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ESTIMATION OF FALL QUAIL POPULATIONS IN IOWA[1]

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In 1938, Bennett and Hendrickson (1938) proposed a technique for censusing the eastern bobwhite, *Colinus v. virginianus*, in early fall, which was adopted by the Iowa State Conservation Commission. Briefly, the technique consisted of censusing a number of quail covey ranges in late August or early September with bird dogs. The time of day selected was from 6:00 a.m. to 8:00 a.m., when cool temperatures and dew facilitated the use of bird dogs. Observations were recorded within a covey range on the number of birds flushed and/or signs observed, such as tracks, dusting and roosting sites, and droppings.

By 1939, the census technique was adopted for 35 counties with the instructions that three covey ranges be censused in the northern part of a county, three in the central part, and three in the southern part by the conservation officer and, if possible, an interested sportsman. The officer was given a two-week period in which to conduct the survey as he usually was responsible for two and sometimes three counties. This procedure has been followed since 1939 with a varying number of counties and with some deviation from the original plan. Many officers were unable to check nine coverts in each county, especially during World War II with its gasoline restrictions, and curtailed their censusing efforts to one or two of the three geographical areas. Another limitation on the utility of the data was the lack of agreement among officers as to what constituted a quail range. Generally, a quail range was depicted as an area of varying acreage in which one would expect to find quail during the fall of the year. Some officers checked one acre of quail habitat, whereas others checked 50 or 60 acres with little annual consistency. No restrictions were placed on the officers as to the specific quail ranges to be selected for censusing in any given year, nor was any plan developed for rotating the sample of covey ranges on an annual basis.

In analyzing the annual data from 1939 through 1953 for 32 counties, the most reliable criterion was considered to be the percentage of observed covey ranges wherein the presence of quail was indicated by flushing the birds or by sign, such as roosting or dusting sites and/or droppings. Because the selection of covey ranges was based on judgment and their location varied from year to year, it was not possible to make any statistical evaluation of the data. A graphic presentation of these data, which were gathered in a subjective manner, indicate a decrease from about 90 to 50 per cent occupancy with a gradual decline in the percentage of occupied covey range over the 15-year period (Fig. 1). Biologists and sportsmen agree that the peak year was 1939 and that the quail population has declined, but there is no general agreement on the extent of the decline. The number of covey ranges that have been checked each fall has decreased from 257 to 153 in belief that the

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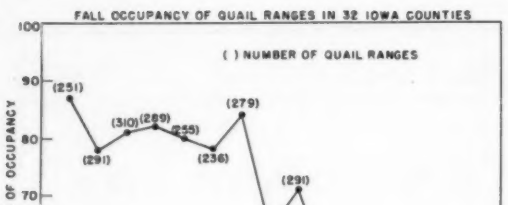

FIG. 1. The percentage occupancy of fall quail ranges in Iowa, 1939–1953.

smaller number sufficed. The summer whistle count (Bennitt, 1951) has supplemented the covey counts in late years.

The relationship between the fall occupancy of covey ranges and hunting success was analyzed. Since 1946 field bag checks have been made by the conservation officers while on routine checks during the open season. The correlation analysis of the percentage of occupied quail range and hunting success (unit of time necessary to harvest a bird) was -0.538, which was not statistically different from "0" (r, at probability level .05, with 6 d.f. = $\pm.707$). Therefore, the present sampling method of occupied quail ranges provides little information on hunting success. In addition, since both the percentage occupancy of fall quail ranges and hunting success data are presently estimated by subjective measurements, questions may well be raised on the accuracy and usefulness of the results.

In compliance with the biological balance law in Iowa the task is to learn the status of quail population in the state and to estimate autumn population shifts from year to year within some specified limits of precision. Recent advancements and application of sampling procedures (for example, Cochran, 1953) suggest that it may be possible to improve the estimates of the fall quail population. Also, the potentialities of using aerial photographs to classify units of land into various class types has been demonstrated (Leedy, 1948). In Iowa aerial photographs of each county on the scale of 8 inches to a mile, available through the county office of the Agricultural Stabilization and Conservation Committee (A.S.C.), greatly facilitate examination and classification of large areas of potential quail range with a modest expenditure of money and time. Therefore, it is possible to quickly classify the land within a county into classes of "good", "fair", and "poor" quail covey ranges between mid-August and March. If samples of ranges are drawn within these classes we can expect an increased precision in our population estimates over that obtained if samples are drawn without this information.

The concept of a "covey range" is such that there may be a lack of agreement among individuals as to whether a particular area constitutes a covey range or not. It is especially difficult to determine the boundaries of a covey range. These obstacles can be avoided if a definite area of land, such as 1/16 of a Public Land Survey section (approximately 40 acres), is used as the survey unit. In Iowa these forties represent a basic land unit and are usually of sufficient size to hold a covey of quail, providing certain habitat requirements are satisfied. The boundaries of these forties are easily seen as fencerows, roads, or some convenient multiple of a larger field. Then, by interpreting habitat types by aerial photo inspection, one may classify the forties into A—good quail range, B—fair quail range, and C—poor quail range. Because habitat requirements of quail change from August to March, the appropriate classification depends to some extent on the time of the year that the annual census is to be taken. With the establishment of a universe of A, B, or C forties with respect to a given time of the year, our plan is to select a sample of such forties from the entire quail range and to determine how many of these forties are occupied by quail at the time of the survey.

The establishment of the universe of A, B, and C forties can be done at each county office for the A.S.C. during the winter months by the conservation officer assigned to the county. Experience during the past summer indicated that, after a little preliminary orientation with aerial photos, particularly the study of a photo of an area familiar to the observer, about two minutes were necessary to classify the 16 forties of an average section of land. The orientation period helps in recognizing cover components valuable to quail, such as row crops,

vegetated waterways, woody cover, and wooded pastures, on aerial photos and hence in the classification of the forties in accordance to the set of criteria adopted.

The average officer will require about three to four working days to complete a county. Although the officers will be given a common set of instructions in aerial photo interpretation, some differences in classification among the 30 or more men involved for 60 counties will be expected, but these differences will cause little effect on the sampling error, which is calculable, and none on bias. After the officer completes the identification and classification of each forty in his county, the information is to be forwarded to the State quail biologist. The biologist assigns, according to the sampling scheme employed, the specific number and the location of A, B and C forties to be censused that fall to each officer in each county. Several sampling schemes and annual replacement of sample forties will be discussed later.

One may consider the problem of population estimation as concerned with either of two goals, the determination of: (1) the hunting potential and (2) the population status. Under (1) one might take the census in October and concentrate all efforts into censusing Type A forties, which are the land units that will bear the major portion of the hunting pressure and obtain no information on occupancy in the B and C forties. This latter group of forties is important in some years when the birds have not moved into the usual fall habitat, possibly due to weather conditions. The estimate would help predict the success of hunters in finding quail in normal years when their hunting would be confined to A forties. With (2) one would attempt to census some of all types of forties and would lose some information on the Type A forties, but would be able to predict the population status for the entire range and not just that segment where the majority of hunting is expected. With the concept of the biological balance law in Iowa, we have chosen to determine the population status of quail throughout the 60 counties.

Inasmuch as it is always difficult to establish the exact number of birds on a given land unit, we shall confine ourselves with the problem of determining only whether a given forty is or is not occupied by quail. Although the exact criterion or set of criteria to be used in the field for determining occupancy will have to be decided upon, field experience in Iowa suggests that the following information be gathered on each forty. When the officer seeks permission to examine a sample forty, the farmer can be interviewed as to determine whether or not he has seen any quail on the forty. If he has, the approximate number and date should be recorded. It is not satisfactory to consider the replies of the farmers alone, for they vary considerably in their interest in quail and somewhat in ability to identify quail. While checking the forty with a bird dog, quail signs, such as dusting areas, droppings, roosting sites, tracks, and whistling, should be noted. All of these observations should be kept separate on a tally sheet for each sample forty. The boundaries and all cover edges within the forty acres should be walked. Weather conditions, especially wind, temperature, and precipitation, should be recorded for each forty in addition to the time of day that the check is made. Rain tends to eliminate quail signs, and at present it is not deemed advisable to check forties until two days after a rain of 0.1 inch or more. In August time of day is important, because bird dogs lose efficiency rapidly after 8:00 a.m. and can seldom be used again prior to 5:30 p.m. Standard Time. The data sheets for all the forties assigned to a given officer are then forwarded to the state quail biologist, who compiles the data for the entire range and computes the estimate of the population or the change in population from the previous year as well as the confidence limits for these estimates.

An important by-product of this annual analysis of population shifts is that since new aerial photographs are made usually about every 10 years for the various counties in Iowa a re-evaluation of the A, B, and C forties can be used as a basis for estimating the rate of improvement or deterioration of the entire quail range. Such information would be valuable in determining the success of game habitat improvement and educational programs or in reflecting the influence of modern farm cultural practices.

SOME SAMPLING SCHEMES COMPARED

To devise the most efficient sampling scheme for the 60 counties comprising the Iowa quail range, data must be accumulated

for a period of years. At present we can speculate on the relative efficiency of various schemes based on the information on occupancy from 1949 through 1953 for 116 forties of the Decatur County Quail Research Area, on privately-owned farm land. Each October, during this five-year period, each of the 116 forties were checked with bird dogs and all farm operators were interviewed. A late October census on the 116 forties revealed 21 coveys in 1950, 29 coveys in 1951, 31 coveys in 1952, and 23 coveys in 1953. The occupancy of a 40-acre tract was accepted only when a covey of quail were observed.

Aerial photographs covering the 116 forties were available and a simple scheme for classifying each forty into one of three type classes was based on the availability and location of food and escape cover. The most important food items for quail in October in southern Iowa are cultivated grains, especially corn, and weed seeds associated with these row crops. Evidence of row cropping can be interpreted from an aerial photograph. Escape cover is usually in the form of wooded gullies or pastures and/or woodlots, which are easy to recognize on an aerial photo. Using sign of row cropping as evidence of sufficient food and woody areas of three acres or more on a forty as evidence of sufficient escape cover, we established three type classes by inspection of aerial photographs. Type A forties were those that contained a minimum of three acres of escape cover within 100 feet of row crops. Type B forties contained a minimum of three acres of escape cover without evidence of row crops, or the five acres of escape cover was more than 100 feet away from row crops. Type C forties included all other forties, except those entirely or partially in incorporated towns or represented as bodies of water, which were excluded from classification. On the Decatur Area it was assumed that nearly all forties contained sufficient roosting cover. We expected to find the highest percentage of quail occupancy in the A forties and the lowest percentage in the C forties.

Two observers were briefly trained on the scheme of classification and were asked to classify the 116 forties (Table 1). Each of the 16 forties on a section were numbered in the same manner as the sections within an Iowa township. Observer I had done some quail censusing on the Decatur Area prior to 1945, whereas Observer II had not seen the Area. In order to avoid possible bias, the classification by Observer II was selected as the set of data to analyze.

TABLE 1.—DIFFERENCE BETWEEN OBSERVERS IN CLASSIFYING 116 FORTIES THROUGH AERIAL PHOTO INTERPRETATION FOR THEIR POTENTIAL OCTOBER OCCUPANCY BY QUAIL

Forty Classification	Observer I		Observer II	
	No. of Forties	Percentage of Total	No. of Forties	Percentage of Total
A.....	58	50.0	66	56.9
B.....	34	29.3	28	24.1
C.....	24	20.7	22	19.0

Records of occupancy by quail for each forty during the five-year period were then compiled for the A, B, and C forties. From these data the yearly probabilities of occupancy and the five-year average were computed. The standard deviation for each year and the five-year average were determined for the three categories, as well as the annual and average correlations of occupancy for four years (Table 2).

TABLE 2.—FRACTIONS OF 116 FORTIES OCCUPIED BY QUAIL, STANDARD DEVIATIONS, AND YEAR-TO-YEAR CORRELATIONS BY CLASS AND BY YEAR, DECATUR COUNTY AREA

Forty Type	5-year average	1949	1950	1951	1952	1953
			P_i			
A.....	.321	.273	.410	.333	.273	.318
B.....	.100	.036	.071	.178	.107	.107
C.....	.045	.000	.136	.045	.045	.045
			σ_i			
A.....	.464	.446	.491	.471	.446	.466
B.....	.289	.186	.257	.383	.309	.309
C.....	.151	.000	.000	.343	.207	.207
			ρ_i			
	4-year average	1949/ 1950	1950/ 1951	1951/ 1952	1952/ 1953	
A.....	.242	.361	.122	.245	.239	
B.....	.218	−.053	.233	.441	.253	
C.....	.126	.000	.000	.549	−.047	

Before attempting to estimate efficiency of various sampling schemes, a judgment appraisal was made of the frequency that one would expect to find A, B, and C forties

throughout Iowa's quail range. On the Decatur Area (Table 1), we found 57 per cent A's, 24 per cent B's, and 19 per cent C's, whereas our expectation for the 60 counties comprising the quail range is 25 per cent A's, 25 per cent B's, and 50 per cent C's. The Decatur Area represents some of the best quail range in Iowa.

ANNUAL ESTIMATION OF OCCUPIED FORTIES—Assuming that the three type classes have the frequency of occurrence of 25 per cent A's, 25 per cent B's, and 50 per cent C's and the same general properties as the Decatur Area, we can conjecture on the resulting efficiencies of different sampling designs in estimating the total occupancy of forties within any one year.

In simple random sampling type classification of forties is ignored and the forties are sampled on a random basis. Stratified random sampling with proportional allocation uses type classes as strata wherein the sampling is proportionate to the class sizes, *i.e.*, 25 per cent A's, 25 per cent B's, and 50 per cent C's. Stratified random sampling with optimum allocation also uses type of classes as strata but the sample is allocated proportional to the product of class sizes and standard deviation instead of size alone (Cochran, 1953).

To compare the efficiency of simple random sampling of forties with those of stratified random sampling, we compare the variances of the sample estimates expected from each. Calculation of the expected variances of the three schemes (Table 4) from the data in Table 3 indicate that a gain in efficiency due to stratification into three type classes with porportional allocation is 30 per cent and with optimum allocation, 60 per cent over simple random sampling. Stated in another way proportionally allocated and optimally allocated stratified samples would need to be only 77 per cent and 62 per cent as large as random samples for the same accuracy.

A sample based on stratification by types and optimum allocation would have the allocation shown (Table 5). Optimum allocation makes sampling nearly twice as intensive in the forties where quail are expected (Class A) and only about half as intensive in the forties where quail are not expected (Type C). In the above sampling schemes we are considering the problem of estimating the total number of occupied forties in any one year.

TABLE 3.—ASSUMED CHARACTERISTICS OF 60 COUNTIES, BASED ON DECATUR COUNTY QUAIL RESEARCH AREA

Forty Type	Fraction of All Forties: W_i	Average Proportion of Occupied Forties: P_i	Average Standard Deviation: σ_i	Average Year-to-Year Correlation: ρ_i
A.....	.25	.321	.464	.242
B.....	.25	.100	.289	.218
C.....	.50	.045	.151	.126
All Types	1.00	.128	.334	.313

TABLE 4.—COMPARISON OF THREE SAMPLING SCHEMES AND THEIR RELATIVE EFFICIENCIES FOR SINGLE YEAR ESTIMATES

Sampling Scheme	Variance of Estimated Total	Relative Efficiency (Random = 100%)
Simple random	N^2/n (0.1115)	100
Stratified random, proportional allocation	N^2/n (0.0861)	130
Stratified random, optimum allocation	N^2/n (0.0696)	160

TABLE 5.—ALLOCATION OF SAMPLE BASED ON STRATIFICATION BY CLASS TYPES AND OPTIMUM ALLOCATION FOR SINGLE YEAR ESTIMATES

Forty Type	Percentage in Universe	Standard Deviation (Five-year average)	Percentage in Sample
A.....	25	0.464	44
B.....	25	0.289	27
C.....	50	0.151	29
Total.....	100	0.334	100

ESTIMATING YEAR-TO-YEAR CHANGE—When a year-to-year change is estimated, it is sometimes advisable to retain (match) the same forties, or some portion of them, in the sample for two or more years, providing there is a correlation between years in the quail occupancy of the same forties. The average correlation over all three classes was +.313 on the Decatur Area; however, it should be remembered that we were basing quail occupancy during the five-year period

TABLE 6.—EXPECTED VARIANCES OF ESTIMATED YEAR-TO-YEAR CHANGES IN NUMBER OF OCCUPIED FORTIES AND THE EFFICIENCIES OF SEVERAL SAMPLING SCHEMES

Sampling Scheme	Estimator	Expected Variance	Relative Efficiency Percentage
Simple random, unmatched	$\overline{X}_2 / \overline{X}_1$	13.30	100
Simple random, matched	$\overline{X}_2 / \overline{X}_1$	9.14	146
Stratified random, prop. alloc., unmatched	$\sum_i^{W_i} \left(\frac{\overline{X}_{2i}}{\overline{X}_{1i}} \right)$	14.30	93
Stratified random, prop. alloc., matched	"	12.13	110
Stratified random, opt. alloc., unmatched	"	10.32	129
Stratified random, opt. alloc., matched	"	9.13	145

on actual observation of the birds and were covering all forties in a block of about 4640 acres. On a few occasions, we found birds on a C forty, adjoining a "non-occupied" A forty. If time had permitted a careful examination of the A forty, quail sign probably would have been observed, for very probably the quail actually spent most of their time on the A forty. So, the average correlation of .313 is probably conservative for this relationship. However, the possibilities of matching in estimating year-to-year change can be conjectured (Table 6).

The results indicate that at present a simple random sample of matched forties from year-to-year is about the same in efficiency as the stratified random with optimum allocation of matched forties. This suggests that the matching of forties is important in estimating year-to-year change and that stratification with optimum allocation provides little further gain in efficiency. However, since the variance formula for a ratio estimator is only an approximation to the true variance, it is believed that a slight gain would be made above simple random sampling with matched forties. Also, stratification with optimum allocation provides the best estimate of occupied forties for any one year, which means that sampling schemes can be identical for either estimating the occupied forties for a given year or estimating the change in occupancy of forties.

In field operation the most efficient design for estimating year-to-year change will probably be partial matching, where data collected over a period of years is fully utilized in the estimates for any one year.

SAMPLE SIZE—After study of the sampling schemes and the determination of estimates of variances for each scheme, the importance of sample size at various levels of precision may be investigated in estimating year-to-year changes or in estimating the total number of forties occupied by quail in any one year. For our example, let us set the precision requirements at the 95 per cent confidence limits; that is, for 95 per cent of our estimates we want the true value to lie within our stated limits. Also, since the optimum allocation of sample forties turns out to be about 50 per cent A's, 25 per cent B's, and 25 per cent C's for the 60 counties, we can assign multiples of four to an officer per county, and we can expect the average officer to be able to census either 8 or 12 forties with a working rate in October of four forties per day.

A 23.9 per cent change is necessary in the proportion of occupied forties from one year to another in order that a population shift will be detected by the survey with 95 per cent confidence (Table 7). For example, if the proportion of occupied forties rises from .128 to .159, an upward population shift would be indicated with only a 1 in 20 chance of being wrong. Also, from Table 7 we see that there is a 22 per cent gain in precision when 12 rather than 8 forties per county are sampled.

In establishing confidence limits we have used the normal approximation. If greater accuracy is desired or the mean occupancy

TABLE 7.—COMPARISON OF ESTIMATES OF QUAIL POPULATION SHIFTS FOR 60 IOWA COUNTIES WITH AND WITHOUT MATCHING OF FORTIES

Sampling Method	Estimated Variances s^2	No. of Forties per County	Percentage Change Necessary to Estimate Population Shift (95% C.I.)
A*.....	0.0696	8	37.4
A.....	0.0696	12	30.6
B**.....	9.13	8	29.3
B.....	9.13	12	23.9

* A Stratified random, optimum allocation, no matching. Estimate of occupied forties in any one year.

** B Stratified random, optimum allocation with matching of forties or simple random sampling with matching of forties. Estimate of a change in the population on a year-to-year basis.

per forty lies outside the range of validity of the normal approximation, reference may be made to charts of the confidence limits of the hypergeometric function by Chung and DeLury (1950). In case of a small mean ($p < .05$) the more appropriate confidence limits may be those of the Poisson frequency distribution (Ricker, 1937).

APPLICATION

From the standpoint of administration, in an early setting of an open quail season it would be helpful to have data obtained by any of the described sampling schemes prior to September 1. But, in this early census we lose in sampling efficiency, observer efficiency, and perhaps in biological information. In August we have an abundance of quail food, insects and weed seeds, on nearly all forties, and it is more difficult to distinguish between an A and B type forty on the basis of aerial photograph inspection. Quail broods are more widely scattered and efficiency gains due to stratification by type classes would be less. Officers cannot work bird dogs successfully and check more than one forty in the morning and one in the late afternoon in late August, whereas in October the daily sampling rate could be doubled to four forties per day. Also, in years of adequate rainfall an abundance of vegetative cover impedes the location of quail sign and hence increases the time necessary to check a forty for quail occupancy. From the biological standpoint data on the status of the quail crop just prior to the open season, usually November 1, would be desirable. Perhaps the season can be set on the data from whistle and brood counts and then changed by administrative order, if necessary, on the basis of the fall counts.

It should be remembered that at present the whistle and brood counts serve only as indices of potential quail production. The October count of quail occupancy of forties is the only objective measurement by which we can estimate quail production within specified limits of statistical precision.

SUMMARY

1. The fall quail census data are summarized from 1939 through 1953 for 32 Iowa counties. The percentage of occupied ranges show a peak in 1939 and a low point in 1953.

2. The possibility of using probability (random) sample of forties (land units of about 40 acres) is discussed as a means of estimating annual population changes within specified limits of precision as opposed to the present judgment sample.

3. Aerial photographs are shown to present an effective means of increasing the efficiency of random sampling by permitting the rapid classification of our quail range universe into three types of forties or strata, which are based on likelihood of quail occupancy in October.

4. Three sampling schemes are investigated: simple random, stratified random with proportional allocation of forties and stratified random with optimum allocation of forties; the last is 60 per cent more efficient than simple random sampling in estimating the proportion of occupied forties for any given year.

5. The analysis of year-to-year change in occupancy of forties, with and without matching of forties, shows that with matching either the simple random sample or the stratified random sample with optimum allocation are about equally efficient; the latter sampling method furnishes one sampling scheme for providing an estimate of the occupied forties in any given year and the year-to-year changes.

6. With either a simple random sample with complete matching of forties or a stratified random sample with optimum allocation and complete matching at a sampling rate of 12 forties per county, an estimated percentage change of 23.9 per cent in the proportion of forties occupied by quail is necessary to estimate a population shift with the 95 per cent confidence interval for the 60 counties.

7. Incomplete matching with stratified optimum allocation will probably provide the most efficient scheme for estimating year-to-year changes in quail occupancy of forties. Data and experience need to be acquired before the most efficient rate of year-to-year matching can be determined.

8. From the standpoints of observer and statistical efficiency and biological information, October is a better time than August in which to conduct the quail population estimate.

LITERATURE CITED

BENNETT, L. J. and G. O. HENDRICKSON. 1938. Censusing quail in early fall. Jour. Wildl. Mgt., **2**: 169–171.

BENNITT, R. 1951. Some aspects of Missouri quail and quail hunting. Mo. Cons. Comm., Tech. Bull. No. 2, 51 pp.

CHUNG, J. L. and D. B. DELURY. 1950. Confidence limits for the hypergeometric distribution. Univ. of Toronto Press.

COCHRAN, W. G. 1953. Sampling techniques. John Wiley & Sons, Inc., N. Y., 330 pp.

LEEDY, D. L. 1948. Aerial photographs, their interpretation and suggested uses in wildlife management. Jour. Wildl. Mgt., **12**: 191–210.

RICKER, W. E. 1937. The concept of confidence or fiducial limits applied to the Poisson frequency distribution. J. Amer. Stat. Assoc., **32**: 349–356.

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AN APPRAISAL OF BICOLOR LESPEDEZA IN QUAIL MANAGEMENT [1]

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Perhaps nowhere within the bobwhite's range have land-use patterns changed more than in the Southeast. Here the shift from "patch-farming" to a more diversified and mechanized agriculture, involving pasture and timber production, has had a catastrophic influence on quail habitat. So great has this adverse effect been that compatibility of quail production with modern land-use practices may well be questioned.

Considerable idle land and small fields worked with mules characterized the old system. Corn and hayfields, interspersed with cotton, provided feed for livestock and habitat for quail. Unimproved pastures, usually on the poorest land, produced plants which furnished quail food. Open woodlands that were burned annually provided suitable low ground cover and formed an important part of the bobwhite's habitat. This combination of circumstances yielded an environment ideal for quail, without benefit of planned "game management."

The new look in Southeastern agriculture is characterized by improved pastures which supply more protein for livestock but offer little to the bobwhite. Mechanized farm equipment for tilling and harvesting cropfields has eliminated idle land, once extensively used by quail. And now that forestry recommendations emphasize fire protection, woodlands are rarely burned and ground cover generally is too dense for quail. As a result of these habitat changes, quail populations have declined throughout the Southeast.

[1] This study is a contribution from the Patuxent Research Refuge, Laurel, Maryland, of the Branch of Wildlife Research and a part of the Service program of Wildlife Investigations on Agricultural Lands.

Help in the statistical analysis was secured from E. F. Schultz, Jr., Agricultural Experiment Station, Alabama Polytechnic Institute, Auburn, Alabama and A. L. Finkner, Department of Experimental Statistics, North Carolina State College, Raleigh, North Carolina. Durward L. Allen, Purdue University, Lafayette, Indiana and William H. Marshall, University of Minnesota, St. Paul, Minnesota, critically read the manuscript. Owners, managers and other plantation personnel who remain anonymous gave invaluable aid to make this study possible.

Return to the old "patch-farming" system would, of course, be undesirable. Consequently, biologists have tried to develop habitat improvements for quail that can be incorporated into a modern agricultural program without lowering its efficiency. The bicolor lespedeza strip, used as a woods border in the farming program was believed to meet this need and has been widely advocated as a management measure for bobwhite quail (Davison, 1941, 1945, 1946a, 1946b, 1948). Marshall (1953), as a result of a general survey in this area, raised several questions regarding the use of bicolor. The Fish and Wildlife Service, the federal agency primarily responsible for wildlife research, initiated studies on land-use in relation to wildlife management at the request of the Soil Conservation Service in 1946. Verne E. Davison, Regional Biologist, SCS, cooperated in the work reported here by recommending some of the areas for study and providing maps.

PROCEDURE

An important asset in this study has been the assistance given by owners and others connected with quail preserves, who cooperated in the work. Their participation included the recording of field observations and results of censusing of birds, saving of crops and wings of shot birds, and modifying farm management plans to permit evaluation of bicolor. These generous cooperators also gave freely of their time in locating coveys and spotting them on aerial photographs. This type of help was obtained from nine preserves having a combined total of 18,777 acres of study areas. On these areas, the locations of 1,924 coveys were mapped and wings of 9,712 birds killed by hunters were saved for determination of age and sex composition of populations. Although the primary purpose of the study was to test the effects of border plantings applicable to small farms, large quail preserves offered an unusual opportunity to collect masses of information that could not be obtained readily from smaller farms.

To facilitate operations, study areas were centered in two states: in Alabama near Union Springs and in South Carolina near Ridgeland, Georgetown and Pineville. The Alabama tracts are located in Black Belt and Coastal Plain soil series while those of South Carolina are in the Coastal Plain. Areas were of many types, *i.e.*, with varying amounts of crop and idle land and woodlands of different tree species.

To enable comparisons, an attempt was made to match each experimental area having bicolor strips, with a similar area to serve as a control. However, it is seldom that two areas can be found in which all environmental factors are equal. Also, unavoidable changes in management or ecology during the study diminished the adequacy of the controls.

Bicolor strips on the study areas differed as to amount and quality of plants as well as in time and method of planting. Some bicolor was present at the time studies began, but during the investigation 500,000 seedlings were planted in approximately 500 strips. They usually were five rows wide and 300 feet long (Rosene, 1953). Most of the experimental planting stock came from the Soil Conservation Service and the Alabama Department of Conservation, Pittman-Robertson Program.

The vigor and productivity of bicolor plantings, and the degree of weed growth in the planted strips were noted periodically. At each inspection, the strips were rated as good, fair, or poor. Thrifty stands of bicolor generally shade out weeds and yield an abundance of seeds (Rosene, 1952, 1953, 1955). Absence of weeds in bicolor strips enables bobwhites to find fallen seeds readily. Plantings with many weeds or scant seed production were given a poor rating. Standards used for classification are as follows:

Good—More than 90 per cent of the ground beneath the plants clear of weeds; producing an abundance of seed.

Fair—Fifty per cent to 90 per cent of ground clear of weeds; seed production average.

Poor—Less than 50 per cent of ground clear; seed production small.

Quail censuses were taken from fall to spring by preserve owners, managers and guides, with the aid of bird dogs. Censusing began when dog conditioning started, shortly before the hunting season opened. In both Alabama and South Carolina, the season opens the latter part of November, closing February 20 in Alabama and March 1 in South Carolina. The counts continued until just before coveys broke up, around April 1.

Resulting information on covey locations, size of area used by each covey, and numbers of birds before and after the hunting season were recorded on aerial photographs.

COMPARISON OF QUAIL NUMBERS ON AREAS WITH AND WITHOUT BICOLOR

Judging the effects of bicolor plantings in a quail management program requires interpretation and evaluation of environmental changes and other local factors. The findings reported here represent the combined experience of the investigator and staffs of the various preserves.

Data on winter populations on the various units are summarized in Table 1. Populations are expressed in coveys per 100 acres. At the beginning of the hunting season birds per covey averaged 14.9 on the experimental areas and 14.0 on the controls, at the close of the hunting season 10.4 and 10.0 respectively.

The higher quail-production potential that the Alabama areas appeared to have is substantiated in the results. Hunters reported poor quail hunting throughout the Southeast during this study, except in 1953–54. Yearly averages on all areas have shown declining populations preceding the "low" in 1949–50, with a gradual annual increase since that season. This same down-and-up population trend occurred on individual areas where maintenance resulted in a stable environment.

ALABAMA 1: Both the experimental and control areas maintained higher quail populations than other tracts throughout the study (Table 1). Management practices on each were similar for seven consecutive years. They produced an abundance of quail foods and maintained excellent cover conditions.

The fact that the control had more quail than the experimental area, except for 1953–54, can be explained in part by the plantation manager's observation that the control always held more quail in the past. The exception in 1953–54 probably resulted from dry conditions in the summer of 1953 which caused the failure of annual food strips and might have resulted in low seed yields of native quail food. This might have caused

TABLE 1.—WINTER QUAIL POPULATIONS ON EXPERIMENTAL AREAS PLANTED WITH BICOLOR STRIPS AND ON CONTROLS WITHOUT BICOLOR

Area	Acreage	Coveys per 100 Acres						
		1947–48	1948–49	1949–50	1950–51	1951–52	1952–53	1953–54
Alabama 1								
Experimental	513	2.3	3.1	3.0	3.1	3.1	3.7	4.4
Control	595	3.1	3.7	3.4	4.4	4.4	4.5	4.4
Alabama 2								
Experimental	844	...	3.5	2.9	1.2	2.3	2.3	...
Control	821	...	5.8	3.1	1.0	2.6	1.7	...
Alabama 3								
Experimental	3360	...	...	2.1	2.6	1.3	2.2	2.6
Alabama 4								
Control	3664	...	...	...	1.4	1.5	1.9	2.2
South Carolina 1								
Experimental	875	...	1.8	2.6	2.5	2.4	1.8	2.1
Control	988	...	1.4	2.2	2.4	1.2	1.4	.8
South Carolina 2								
Experimental	1213	...	1.7	.8	1.1	1.1	.8	.9
Control	1129	...	.7	.4	...	...	.9	1.0
South Carolina 3								
Experimental	530	...	...	1.1	1.1	2.1	3.4	2.8
South Carolina 4								
Experimental	2500	...	...	2.6	2.6	3.4	2.1	1.9
South Carolina 5								
Experimental	895	...	1.5	1.4	1.3	2.0	1.5	2.2
Control	850	...	1.2	1.1	.5	1.1	1.2	1.5

movement of quail to the bicolor.

Evidence from these areas indicates strongly that in places where natural food and cover conditions are favorable, bicolor is of slight significance as a management measure.

ALABAMA 2: Here, also, the control was superior to the experimental area at the outset of the study. Population changes were influenced chiefly by factors other than bicolor. In the fall of 1950–51 the population was similar to that of the previous year, but after extensive training of field-trial dogs on both areas all winter, a sharp reduction appeared in spring. Another factor which had a depressing effect on the population was excessive burning from 1949 through 1952, which resulted in depletion of nesting cover below minimum needs of the available breeding population. Part of the control tract was plowed and sown to pasture grass in the spring of 1952. This land-use change contributed still further to the reduction. A conclusion to be drawn from this area is that bicolor did not compensate for adverse factors affecting quail production.

ALABAMA 3 AND 4: These two areas were sufficiently alike to be considered together, Alabama 4 serving as a control for Alabama 3. The planting of numerous bicolor strips on Alabama 3 failed to produce satisfactory increases in quail. The treated area had 139 strips in 1950, 169 in 1952, and 200 in 1954. The quail population increased slightly during this period (Table 1). Factors other than bicolor appeared to have played an important part in this result. Undesirable fire on Alabama 3 in the spring of 1951 may have been responsible for the severe reduction in population the following winter.

At the close of the 1951–52 hunting season, 58 bicolor strips were used by 42 coveys, whereas 111 strips were unused. Next year, with a successful nesting season, the population almost doubled and 63 coveys used 61 strips, all of which were classified as good or fair, whereas 99 strips were unused. Eleven covey ranges were not in bicolor. Quail scratch little in search of seeds so prefer to feed in plantings where seeds fall upon a surface relatively free of duff and are easily found. Consequently, plantings classed as good are preferred over fair ones and use of poor plantings is uncommon.

In the spring of 1954, bicolor strips were used by 77 coveys whereas 10 coveys did not use bicolor. Alabama 4 had a lower population of quail than Alabama 3, the experimental area, yet demonstrated an increase each year due to management practices other than planting of bicolor. On the experimental area, the population fluctuated, even with numerous bicolor plantings. The increase in the number of bicolor strips from 1950–54 did not reflect corresponding increases in quail, whereas judicious management on the control produced annual increases.

SOUTH CAROLINA 1: Insufficient burning was done on the experimental area, so by the 1948–49 hunting season the population had declined from previous years as the cover became too thick. Strip disking was used as a supplemental management practice in the spring of 1949 and its beneficial effects could be seen in the 1949–50 winter population and the two following hunting seasons.

The control was satisfactory for comparison until the spring of 1951 when clearing for pasture began on half of this tract and the open fields on the other half were planted to trees with all fire excluded. Populations declined in subsequent years and the importance of land-use practices, other than planting of bicolor, was demonstrated in quail management.

SOUTH CAROLINA 2: These areas demonstrated the value of bicolor in holding pen-reared quail. On both, a shortage of satisfactory nesting cover was judged to be a major factor in depressing the population. Supplies of native foods were also inadequate. The first factor was offset each fall by releasing pen-reared stock in the bicolor strips and in likely coverts on the control. Many of the stocked quail either moved elsewhere or were taken by predators, as at times fewer birds were found during the hunting season on these areas than had been released earlier in the fall. Usually, some of the bicolor strips were unused each year and a few coveys ranged where no bicolor was planted. On the control, hunting was so poor in 1950–51 and 1951–52 that no records were kept. However, the experimental area had a higher average population throughout the period of study. This was considered a direct result of the food furnished by the bicolor.

SOUTH CAROLINA 3: Bicolor was established on this area before the study started,

and variations in population resulted from other quail management practices. The population in 1949–50 was low because vegetation in the area was too dense for quail. A wildfire in the spring of 1950 was detrimental for the following nesting season, but in subsequent years controlled burning has kept the density of cover more desirable and populations increased. From 1951 through 1953, additional openings were cut in the woodlands and small fields were established. This resulted in better nesting conditions.

SOUTH CAROLINA 4: On this area, an average of 9.6 bicolor strips per 100 acres in the last few years failed to maintain a stable quail population. Low populations were due mainly to excessive burning. At the start of the study, there were 164 bicolor plantings on the area, some of them consisting of two-row strips. Later the number was increased to 245 and two-row strips were increased to five-row. From the 1949–50 hunting season through 1951–52, quail populations increased but since 1952 they declined rapidly. In recent years, the area was burned too thoroughly and shortage of nesting cover is believed to have been the limiting factor. Because of cover shortage, some nesting sites were on damp soils subject to flooding or in other vulnerable situations.

SOUTH CAROLINA 5: In summer, more quail were present on the control than the experimental area while at the opening of the hunting season the reverse was true. This indicated that quail moved between the experimental and control areas. Native winter foods are not abundant on either, so it seemed that the experimental area treated with bicolor strips retained birds produced there and also attracted some produced elsewhere.

BICOLOR *vs.* NATIVE FOODS

During the study, 2,029 quail crops saved from birds shot by hunters were analyzed to determine extent of use of bicolor seed. Table 2 summarizes findings from 822 crops representing four areas where bicolor was growing. Quail make extensive use of bicolor seeds as evidenced by these analyses. On each of the four areas bicolor seeds averaged not less than 32 per cent by volume of total food intake and ranked in importance either first or second on the food list.

Many crop contents consisted wholly of bicolor seeds. Birds obtained from control areas had fed upon a wide variety of native foods, the extent of use of each depending mainly on its relative abundance and availability. Evidently, though quail like bicolor seeds, the extent to which they are eaten depends largely on their abundance and availability as compared with native foods.

No evidence was obtained to indicate that bicolor has any value for nesting cover. Its usefulness is limited almost entirely to improving food conditions. In general, well-tended bicolor is more likely to be used by quail than neglected plantings. Strips classed as good were used in preference to those classed fair or poor. The assumption that quail which feed on bicolor in winter may be in better physical condition by spring and as a result produce more young per hen than those on native food sources was not verified by findings of a population analysis.

DISCUSSION

When the quail population of an area depends mostly on bicolor for food, a large percentage of the coveys are commonly found either in the bicolor strips or in the immediate vicinity of them. Bird dogs on properties having bicolor strips become

TABLE 2.—ANALYSIS OF 822 CROPS COLLECTED ON FOUR PLANTED AREAS DURING 1950–54 INDICATING USE OF BICOLOR SEEDS IN RELATION TO OTHER FOODS

Study Area	Number of Crops	Bicolor in Crops		Other Foods in Crops	Bicolor Rank in Relation to Other Foods
		Per cent by Volume	Per cent Frequency	No. of Kinds	
Alabama 1	50	35.3	64.0	50	1
Alabama 3	573	39.3	56.7	101	1
South Carolina 1	37	32.2	37.8	26	2
South Carolina 4	162	56.5	66.7	66	1

familiar with this characteristic and hunt mostly in bicolor plantings. This makes hunting easier and usually puts more birds in the bag per hour hunted. Excessive kill did not result on the study areas as care was exercised to avoid removing too many birds, either from individual coveys or from the area as a whole. Excessive kills might result on such areas if they were open to public shooting. The fact that bicolor aids in hunting by localizing coveys is a reason for its continued use where this is the desired effect.

Bicolor is a preferred food. Its seeds usually were eaten in preference to other available foods (Table 2). Many individual crops from the experimental areas contained only bicolor. Others had small percentages when adequate bicolor seed was available. On the controls, preference also was shown for seeds from a certain plant species but not to the exclusion of other available foods. This indicates that single birds or individual coveys use one food during a daily feeding period and might at other times prefer a varied diet, whereas other birds or coveys apparently prefer a varied diet at all times. Therefore, these feeding habits indicate that where food is short, bicolor could be expected to correct this fault. On all areas but one (S. C. 2), it appeared that food was not the limiting factor so planting of bicolor did not result in larger populations.

ANALYSIS OF DATA—In most instances experimental and control areas were in relatively close proximity to each other so at completion of the study it was possible to choose six experimental areas with controls, on which quail populations were available. As these were censused each winter throughout the period of study, 64 results or 32 pairs were available for statistical evaluation (Table 1). The mean difference between populations of experimental and controls was found to be 0.8 covey per 1000 acres in favor of the experimental.

To determine if this could be considered as the effect of bicolor planting on populations, analysis of variance table is presented (Table 3).

This indicates that the effect produced by treatment is so small as to be expected in more than 50 per cent of cases even when no dissimilarities are present. Hence, the difference of 0.8 covey per 1000 acres is not to be attributed to the use of bicolor on the experimental tracts and the controls not so treated.

TABLE 3.—ANALYSIS OF VARIANCE FOR 32 EXPERIMENTAL AREAS WITH CONTROLS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Total.....	63	8,466.46	.....	....
Areas.....	31	7,512.97	242.35	....
Treatment...	1	9.74	9.74	0.32*
Error.....	31	943.75	30.44	....

* Not significant (significance requires 4.16 at .05 and 7.53 at .01).

Possibility occurred that the number of quail per covey or quail per 100 acres, at the start and end of the season, might be significant for one type of area. F values from an analysis of variance and the mean differences for these items were determined.

TABLE 4.—F VALUES OF DIFFERENCES BETWEEN EACH TYPE OF AREA FOR THE SEVEN-YEAR PERIOD

	Mean Difference	F Values
Quail per covey		
Start season.....	0.9*	4.15
End season.....	0.4*	4.40
Quail per 100 acres		
Start season.....	6.1*	2.80
End season.....	3.9*	2.73

* In favor of experimental areas.
F values required at 0.05 = 5.99; at .01 = 13.47.

With one and six degrees of freedom these F values are not significant. Any difference between areas by using bicolor was not reflected in the statistical analysis in birds per covey or birds per 100 acres.

Some of the mean difference figures for quail per covey and quail per 100 acres in favor of experimental areas in this study might possibly be found to be significant in a subsequent study if more samples were taken or more of the extraneous variability removed. To accomplish either would be extremely difficult. It is doubtful if the mean difference figures have any practical significance.

SUMMARY AND CONCLUSIONS

The value of lespedeza bicolor to bobwhite quail was studied during the 7-year period

1947–54 on 9 hunting preserves located in Alabama and South Carolina. Findings involve studies on 18,777 acres and are based on mapping and distribution of 1,924 coveys of quail. Over 500,000 bicolor seedlings were planted on the preserves studied. Quail populations on areas planted with bicolor strips were compared with those on control areas not so treated. The extent of use of bicolor in relation to native foods was obtained by analysis of contents of 822 quail crops.

1. Bicolor is a preferred food of the bobwhite and may be of some value in the management of this species in those parts of the Southeast where scarcity of food is a limiting factor.

2. Where native quail foods were plentiful, bicolor plantings failed to increase quail populations.

3. Use of bicolor strips by quail is dependent in part on quality of the planting. In these studies, poor strips did not show any value.

4. Bicolor appears to have had some favorable effect in holding released birds but not to such an extent as to make stocking of game-farm reared birds economical.

5. In winter, bicolor plantings tend to attract and concentrate quail that are produced elsewhere. This tendency may increase the kill and, on preserves where kill is regulated, is a desirable effect. However, on areas where hunting pressure is high it might result in excessive kill.

6. On many areas, some of the bicolor strips remained unused, even with a comparatively high quail population and a relatively small number of plantings. This indicates a deficiency in suitable nesting coverts, particularly where populations are relatively low.

7. Factors such as time and intensity of burning, amount of nesting cover available, land-use practices, and disturbances had greater effect on quail populations than the presence or absence of bicolor.

LITERATURE CITED

DAVISON, V. E. 1941. Wildlife borders—an innovation in farm management. Jour. Wildl. Mgt., **5**: 390–394.

———. 1945. Wildlife values of the lespedezas. Jour. Wildl. Mgt., **9**: 1–9.

———. 1946a. False principles delay advancement in wildlife techniques. Jour. Wildl. Mgt., **10**: 296–299.

———. 1946b. For farms and game preserves, bicolor lespedeza. Better Crops with Plant Food Magazine, **30**(7): 22–27.

———. 1948. Bicolor lespedeza for quail and soil conservation in the Southeast. U. S. Dept. Agr. Leaflet 248: 1–8.

MARSHALL, W. H. 1953. Survey of farm-game habitat restoration programs in fifteen states. Trans. N. Amer. Wildl. Conf., **18**: 390–412.

ROSENE, W., JR. 1952. Care and maintenance of bicolor lespedeza. Soil Conservation, **17**(7): 151–153.

———. 1953. Growing bicolor lespedeza in southeastern states. U.S.D.I., Fish and Wildlife Service, Wildl. Leaflet 350.

———. 1955. Recommendations for the culture of *Lespedeza bicolor*. Jour. Wildl. Mgt., **19**: 84–88.

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A SIMPLE FIELD CANDLER FOR WATERFOWL EGGS[1]

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In nesting studies of waterfowl and other game birds it is often desirable to determine the stages of incubation of clutches of eggs. This information makes it possible to determine when incubation began and to calculate the date of hatching. In some studies, the stage of incubation has been determined by breaking an egg of each clutch. This is an unnecessary waste, and for species which lay parasitically in other birds' nests, such as the redhead and ruddy duck, the breaking of one egg has little value because eggs in a single nest may be in many stages of incubation.

Westerskov (1950) discussed the need for age determination of embryos and presented several methods which he used in the laboratory in working with pheasant and European partridge eggs. These methods were weighing, floating, and candling of eggs.

The use of egg weights in the field necessitates carrying a delicate balance and making calculations from the weights in order to determine the stage of incubation.

In the second method, eggs are floated in water; their buoyancy and position are related to the stage of incubation. While this method is satisfactory for use in the laboratory or for species which nest over water, it is inconvenient for land nesters. This technique permits rapid age determination in the early stages of incubation but becomes less accurate as incubation progresses.

By the use of a laboratory candler, Westerskov found that the size of the air cell and the early development of the embryo were good criteria for determining the stage of incubation of pheasant eggs. The increased density of the yolk mass plus the opacity of the shell reduced visibility so that the embryo could not be seen properly after the first week of incubation; but the size of the air cell proved an excellent criterion throughout. The use of the air cell in candling chicken eggs has been reported by many workers, including Banner (1920), and Lamon (1921).

Candling has been little used in the field because of the lack of simple and efficient equipment. Evans (1951) used a cardboard mailing tube for candling duck eggs in the field; from the comparative size of the air cell, he determined when the eggs were near hatching. Hanson (1954a) developed a battery-operated field candler which provided excellent visibility of many details of the egg. He presented a list of criteria and photographs of eggs at various stages of incubation (1954b).

In order to develop criteria by which the stage of incubation of duck eggs could be determined in the field with the simple mailing tube suggested by Evans, the present study was initiated in the spring of 1952. Twenty-six redhead, ten canvasback, five pintail, and five mallard eggs were candled when brought into the hatchery, found to be fresh, and were placed in an incubator. The development of these eggs was followed with the mailing tube candler.

Candler

The simplicity of the mailing tube is its principal advantage. It can be made sturdy by a coat of shellac and will hold an oval shape, thus reducing light leakage. Any long flexible tube can be used. Evans (personal communication) prefers a large diameter rubber hose (as used in automotive cooling systems) because of its flexibility and durability. A notebook or magazine works well because it can be rolled so that its diameter is slightly less than that of the particular egg being examined. The egg is held tightly against the open end of the candling tube so that its long axis forms a right angle with that of the tube.

[1] Contribution from the Delta Waterfowl Research Station, Delta, Manitoba, and the Missouri Cooperative Wildlife Research Unit: U. S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, Edward K. Love Foundation, and University of Missouri cooperating. The writer wishes to acknowledge the advice and assistance of Wm. H. Elder and T. S. Baskett, Missouri Cooperative Wildlife Research Unit, and H. Albert Hochbaum and Peter Ward, Delta Waterfowl Research Station.

LIGHT SOURCE

The sun, even on cloudy days, provides sufficient illumination. Practice with the tube lends skill in using available light; the egg is usually viewed toward the sun, but can be held slightly away from the sun in order to clarify minor details. The tube should be held so that its shadow falls upon the inner corner of the eye, thus reducing the chance of light leakage between the nose and the candler.

CRITERIA FOR AGE DETERMINATION

The appearance of the developing embryo and its associated structures as seen through the candler are shown in Figure 1. Three views are provided of each stage because changes are often more apparent in one view than in another. There are five criteria which aid in age classification: size of the embryo when visible, shape and appearance of the yolk, development of the extra-embryonic circulatory system, density of the opaque areas, and the size of the air cell. Characteristics of redhead eggs at four day intervals are as follows:

UNINCUBATED—The yolk is barely visible due to its pale yellow color. It is free floating and the air cell is quite small. In unincubated eggs which have been deserted by the female, the yolk soon adheres to the shell membrane and turns brown.

FOUR DAYS—The embryo and the extra-embryonic vascular system are clearly visible and red in color (the "spider" stage of the poultryman). The yolk is yellow-orange and less solid than in the fresh egg. The margin of area vasculosa, the sinus terminalis, is often visible.

EIGHT DAYS—The outline of the embryo is less distinct, appearing as two isolated dark

FIG. 1. Criteria for the determination of the stage of incubation of redhead eggs. Where three views are shown, they are from left to right: (1) Front view, with the embryo adjacent to the viewer, (2) Side view, with the egg rotated 90 degrees to the left, and (3) Rear view, with the egg rotated 180 degrees to the left from the front view.

areas. These are the head and the trunk; the thin neck is barely visible. A rocking motion of the embryo may be seen at this time but is retarded by handling. The yolk now appears to be more solid because it has been enveloped by the yolk sac and in the side view, the sinus terminalis is distinct; its margin may parallel the long axis of the egg or may be diagonal.

Twelve Days—The yolk sac has completely enclosed the yolk except for a small area opposite the embryo where the albumen is attached. The vascularization causes an increased density and less distinct outline of the yolk mass. The growth of the embryo forces the remaining yolk into two lobes, one lying on either side of the duckling. The most opaque areas outline these lobes where they are pressed against the shell. The embryo is indistinctly visible as a dark area isolated from the yolk.

Sixteen Days—When seen from the rear view, this stage differs from that of the twelve day stage in that the light band separating the embryo and the yolk mass is much narrower, due to an obvious increase in the size and opacity of the embryo. The air cell is noticeably larger than in the 12 day stage.

Twenty Days—The egg is now opaque, except for the air cell and the area immediately adjacent, plus a minute area at the small end. The lobes of the yolk mass are barely discernible.

Twenty-two Days—The bill of the duckling is now pressed against the inner shell membrane and is visible as a projection in the air cell.

Hatching occurs at twenty-four to twenty-eight days in the incubator according to Hochbaum (1944), Peter Ward, hatchery superintendent at the Delta Waterfowl Research Station (personal communication), and my own observations.

In embryos which die before hatching, the blood vessels and yolk appear brown. The observer will learn to distinguish these with practice.

Figure 1 and the age criteria described above are satisfactory for other species with a similar incubation period (canvasback and mallard). The pintail, and probably the blue-winged teal, which have an incubation period of 21 to 23 days, can be aged by using these same illustrations if it is realized that the last three stages represent 15, 18, and 20 days of incubation in these species. The technique is not sufficiently refined to make distinctions between species having incubation periods between 21 and 23 days.

Among the species examined, this method worked best with the eggs of the redhead, mallard, blue-winged teal, baldpate, and gadwall; it was more difficult with eggs of canvasback, pintail, and lesser scaup because of the greater density of their shells. The density of the shell structure or coloration was so great in the eggs of the ruddy duck, Canada goose, coot, sharp-tailed grouse, and Hungarian partridge, that the size of the air cell was the only practical criterion.

Literature Cited

Banner, E. L. 1920. The Cornell reading course for the farm, Lesson 156: 329–364. N. Y. State Coll. Agr., Ithaca.

Evans, C. D. 1951. A method of color marking young waterfowl. Jour. Wildl. Mgt., **15**: 101–103.

Hanson, H. C. 1954a. Apparatus for the study of incubated birds' eggs. Jour. Wildl. Mgt., **18**: 191–198.

———. 1954b. Criteria of age of incubated mallard, wood duck, and bob-white quail eggs. Auk., **71**: 267–272.

Hochbaum, H. A. 1944. The canvasback on a prairie marsh. Amer. Wildl. Inst., Washington, D. C. 201 pp.

Lamon, H. M. 1921. The incubation of hens' eggs. Farmer's Bul. 1106. U. S. Dept. of Agric. 8 pp.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. Jour. Wildl. Mgt., **14**: 56–67.

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THE PIKE, *Esox lucius* LINNAEUS, IN RELATION TO WATERFOWL ON THE SENEY NATIONAL WILDLIFE REFUGE, MICHIGAN [1]

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The predatory habits of pike have been recognized by North American biologists for about a hundred years. The special role of the species in limiting waterfowl production has been explored by Bajkov and Shortt (1939), Ross (1940), and in greatest detail by Solman (1945) for the Saskatchewan and Athabaska River deltas in Canada. In these areas it was estimated that approximately 10 per cent (about 1,500,000 individuals) of such birds were destroyed by pike in an average year. In the early years of flooding of the pools on the Seney National Wildlife Refuge (1936 to 1941), concern was felt over the subjectively determined slow increment of the avian population as compared to that of pike, and led to the obvious question of how great a limiting factor the fish were in duck production. The problem of utilizing the obviously extensive pike resource for public enjoyment was also considered, even to the extent of using angling as a method to reduce the fish population if such control seemed desirable. The primary objectives of the investigation were: (1) to determine the nature, extent, and effect of the feeding habits of the northern pike on waterfowl, and (2) to formulate a plan for the management of the northern pike. The work was done at intervals from 1941 through 1953.

Field work was conducted in 1941 from July 4 through 7 and from August 22 through September 23; in 1942, from May 19 to July 31, which covered the period of duck nesting; and in 1943, from June 1 to August 15. Short observation and sampling visits were also made in 1951, 1952 and 1953.

The investigation was instigated by J. Clark Salyer, II, Chief, Branch of Wildlife Refuges, U.S. Fish and Wildlife Service. Field operations were greatly facilitated by the cooperation and kindness of the refuge managers, the late C. S. Johnson and C. J. Henry, and their staffs, particularly Axel Mortenson and William Anderson. The help of other federal employees, especially John van Oosten, colleagues in the University, and many friends and anglers around Seney is gratefully acknowledged. My wife, Mary Jane Lagler, participated extensively in both the field and laboratory aspects of the study.

Description of the Area

The Seney National Wildlife Refuge comprises about 94,000 acres in Schoolcraft County, Michigan, southwest of Seney and west of Germfask. The tract lies in the basin of the Manistique River which flows southwesterly across the eastern lowlands of the Northern Peninsula to enter Lake Michigan. This low-lying physiographic province is poorly drained and much of the region is swampy. Most of it was flooded by glacial Lake Algonquin but not by the earlier Lake Nipissing (Scott, 1920). The sandy subsoil is overlain on the lowest areas by organic material (often fibrous peat). Ridges are interspersed among the plains and marshes of the Seney region and represent sand dunes of retreating levels of Lake Algonquin (Berquist, 1936). The dykes which impound tributaries of the Manistique River on the Refuge were constructed largely along dune lines.

In the decade following 1910, a large extent of the Seney marshes was drained by ditching for agricultural purposes. With the passage of this unsuccessful farming enterprise, the land reverted to plains vegetation

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(mostly sedges) or to swamps with little open water, where beaver dammed ditches and streams. In 1935 the U. S. Fish and Wildlife Service acquired the area and soon began the construction of dykes and water-level-control structures, aided and abetted by beaver (Beard, 1953). The resultant ponding made much good waterfowl habitat but, inadvertently, did the same for pike. The developmental program produced 19 major impoundments or "pools" by 1943. These pools are grouped in three units and have a total area of about 6,000 acres. The date of first filling and approximate water acreage as determined from maps and water levels in the 1940's follow (the figures in parentheses are the estimates of the 1950 conditions made by the refuge staff): Unit I—April, 1936: Goosepen, 40 (50). September, 1936: Lower F, 186 (130); Upper F, 39 (50); Show, 40 (45). April 1937: A, 225 (250); B, 313 (320); C, 271 (220); D, 195 (160); E, 491 (430); G, 172 (115); H, 144 (160); I, 121 (110); J, 221 (180). Unit II—September, 1939: C, 700 (640); A, 800 (500). April 1941: T, 300 (350); M, 1,200 (900). Unit III—September 1942: C, 800 (1,000).

Each pond has had a different history since first flooded and all have undergone extreme variations in water level. Some, such as B and H, have been drawn down as completely as possible for several months at a time in order to repair water regulatory structures or to manage waterfowl habitat. Even during such intervals, however, residual fish populations persisted in undrained depressions. Levels established after drawdown and alteration of control structures have invariably been lower than those first employed.

General Limnology of the Pools

In general physical characteristics, the pools of the Refuge are much alike. The retaining dykes extend predominantly in an east-west direction and thus determine main axes and distribution of depths for most of the impoundments. The average depth of water is between 2 and 3 feet and seldom exceeds 5, except in the borrow pits near the dykes where the extreme water depth is 15 feet.

The margins of the pools are irregular. This feature, coupled with the presence of many small islands, gives a high value for shoreline development. The bottom is predominantly fibrous peat; sand (in borrow pits and along dykes, ridges, and islands) and bog ore (scattered patches) occur only sparingly. The water is varying light brown in color and, because of plankton and turbulence effect of wind on fine bottom materials, it is turbid (Secchi disc readings range only from 2.0 to 9.5 feet).

The principal sources of water, other than precipitation, for the pools are four streams which enter the Refuge from the north: Holland, Walsh, and Marsh Creeks and the Driggs River. Of these, the Driggs is most important and permanent and provides 80 per cent of the area's water supply at lowest stream stages (C. S. Johnson, Quarterly Narrative Report, May-July, 1939).

Surface-water temperatures in pools from late June through early August ranged from 60 to 91°F. but were mostly between 66 and 79. These temperatures fluctuated widely and rapidly but were usually close to the air temperature because of the shallowness of the water. Thermal gradients in borrow pits, however, often exceeded an average decline of 1°F. per foot of depth increase.

Dissolved oxygen in summer was ordinarily at or near saturation except near the bottom of a few of the deeper borrow pits (where it was never completely depleted). Anaerobiosis occurred under the ice cover of pools having little or no stream flow through them as evidenced by occasional winterkill of fish.

The water in the pools was not extremely hard; the methyl orange alkalinity ranged from 27 to 75 ppm. Except for impoundment T in Unit II, which was slightly acid (pH 6.0), pH values ran from 7.2 to 9.7. Pollution did not exist on the Refuge or on its tributaries in an amount that might be biologically significant.

Water plants, although most were submergent, flourished in the pools and constituted one of their most evident biological characteristics. The sources of this vegetation were both natural and artificial. Natural invasion was primarily exemplified by *Anacharis* (*Elodea*) *canadensis*, which apparently came from the streams of the area where it occurred in quiet back-waters upstream from the impoundments. Other plants in this category were *Chara*, *Nitella*, *Polygonum*, *Myriophyllum*, and *Utricularia*. Species planted (but also perhaps of native

origin) include *Najas flexilis, Scirpus* spp., *Vallisneria spiralis, Potamogeton pectinatus,* and, sparingly, *Zizania aquatica.*

Plankton and insect naiads and larvae were abundant in Refuge waters. The most evident plankton was algae which often formed conspicuous surface blooms. Measured volumes of plankton in gravity-concentrated, formalin-preserved samples ranged from 0.1 to 2.3 cc. per 10 gallons of subsurface water and averaged about 0.5 cc.

Chief invertebrates were the aquatic stages of mayflies (Ephemeroptera) and dipteran midges (Ceratopogonidae and Tendipedidae), leeches (Hirudinea), and crayfishes (Decapoda). Numbers of invertebrates other than crayfish ranged from 23 to 748 per square foot of bottom materials, as sampled by Ekman dredge. Many of the kinds represented are of value as food for fish, as well as for waterfowl (shown by duckling food studies made by Uhler and reported by Beard, 1953: 425). The leech and crayfish populations appeared to be more abundant than in nearby natural waters.

Sport fishes and several species which they use for food inhabited the refuge waters. As far as practicable the names employed follow those in Special Publication No. 1 of the American Fisheries Society, 1948.

SPORT FISHES

Esox lucius Linnaeus. Pike. Common in all pools and present in tributary and effluent streams.

Salmo trutta fario Linnaeus. Brown trout. Stocked and seasonally common in streams entering from north.

Salvelinus f. fontinalis (Mitchill). Eastern brook trout. Rare in streams entering from north.

Stizostedion v. vitreum (Mitchill). Yellow walleye. Reported rare following introduction by stocking in Pools E, F, I, and J in 1938. None were seen during this study.

Perca flavescens (Mitchill). Perch. Common in pools.

Lepomis gibbosus (Linnaeus). Pumpkinseed. Common in pools.

Lepomis m. macrochirus Rafinesque. Bluegill. Ripe fish (11 males and 75 females) introduced into Pool I in June 1942. Established sparsely there by 1944 and in Pool F by 1952. Not otherwise encountered in 1941–1943 collections.

Ameiurus n. nebulosus (LeSueur). Northern brown bullhead. Common to abundant in all pools.

FORAGE FISHES

Catostomus c. commersoni (Lacépède). White sucker. Uncommon in pools.

Moxostoma aureolum (LeSueur). Golden redhorse. Rare in pools and streams.

Semotilus a. atromaculatus (Mitchill). Northern creek chub. Uncommon in streams.

Rhinichthys atratulus meleagris Agassiz. Western blacknose dace. Uncommon in swifter portions of streams.

Chrosomus eos Cope. Northern redbelly dace. Common in pools and in their tributaries and outlets.

Notemigonus crysoleuces auratus (Rafinesque). Western golden shiner. Common to abundant in all pools.

Notropis d. dorsalis (Agassiz). Rare in few pools and affluents.

Notropis v. volucellus (Cope). Northern mimic shiner. Rare.

Notropis h. heterolepis Eigenmann and Eigenmann. Northern blacknose shiner. Mostly common to abundant in all pools.

Pimephales p. promelas Rafinesque. Northern fathead minnow. Abundant in pools.

Pimephales notatus (Rafinesque). Bluntnose minnow. Common in pools.

Umbra limi (Kirtland). Western mudminnow. Rare to common in pools, particularly in small isolated parts, including beaver ponds and in marshy affluents.

Hadropterus maculatus (Girard). Blackside darter. Rare in pools, present in tributaries.

Boleosoma n. nigrum (Rafinesque). Central Johnny darter. Rare in pools and affluents; most common on sandy bottom.

Poecilichthys exilis (Girard). Iowa darter. Common to abundant in pools.

Poecilichthys flabellaris lineolatus (Agassiz). Northern fantail. Rare in swifter portions of streams entering from north.

Cottus b. bairdi Girard. Northern muddler. Rare in tributaries.

Eucalia inconstans (Kirtland). Stickleback. Common in rivulet affluents and in marshy portions of pools, including beaver flowages.

CHARACTERISTICS OF PIKE POPULATION

DISTRIBUTION — Although pike were spread throughout the waters of the Refuge,

the distribution was uneven and changed seasonally and with life-history stages. Other than in headwater marshes during spawning season (presumed), locations of greatest concentration of adults were always associated with moving and/or deeper water. In late May, particularly large numbers of adults were found in moderate to strong currents on the downstream sides of various barriers to movement constituted by low dams, spillboxes (where water from one pool would fall a few feet into the next one downstream), gate-valves, etc. These fish were probably post-spawning migrants which had concentrated in the flowing channels after leaving the marshy spawning grounds and before dropping downstream to summer habitat in pools. Similar aggregations, although not so numerous, were found at the dam over which Pool D falls into Pine Creek. Here, however, the concentration extended in some degree throughout the summer as evidenced by occasional hook-and-line catches at the rate of 20 or more per fisherman hour during June through September in various years. In the pools themselves, adult fish were most frequently encountered from June through September in or about the margins of borrow pits. By midsummer, they were characteristically absent from the marshy portions of pools and from those bays or arms in which the water was rusty and turbid from the oxidation of iron. These distributional data are based on hook-and-line catches and on captures in gill nets, fyke nets, and seines.

Young-of-the-year pike were present in the shallowest and quietest parts of the headwater marshes in May and June. By July they had spread to water as much as two feet deep, although most stayed in water less than one foot deep. Throughout the first summer of life these fish remained in this habitat as indicated by periodic seine collections from May through September and on samples obtained in July and August by the use of rotenone.

Rarely, both young and adults became stranded by falling water levels in particular areas of seasonal concentration. Starvation and increased vulnerability to angling and to predation acted as population checks in these locations.

NUMBERS PER UNIT AREA—Although pike are highly predaceous fish, their populations may be relatively dense per unit area in natural waters. Solman (1945) estimated natural populations in June and July of at least 27 individuals per acre in a section of Baptizing Creek, Lower Saskatchewan River Delta. The size of these pike was "large enough to eat ducklings" (*ibid.*, p. 168), which is estimated to be about 14 inches total length. On the Seney Refuge, approximations for comparable calendar intervals were from 10 to 12 per acre for fish of this size and larger as determined in a mark-and-recapture estimate (Schnabel, 1938), and from two poisoning experiments. That a high natural mortality may greatly change such values in a single growing season was shown by Carbine (1944) who found a 99 per cent loss of young-of-the-year from May to October.

The three best population estimates of numbers of pike older than young-of-the-year were for Pool I in Unit I and for Pools T and C in Unit II. Some statements as to certain minimal densities can also be made for other areas.

Pool I yielded 2,569 pike (about 22 per acre of its 120 acres); 560 of these were gill-netted in the spring of 1940, 290 trapped early in 1941, and 1,719 were recovered following treatment with rotenone on July 5–7, 1941. All were eight inches or more in length and were in their second year of life or older. Spot-poisoning of a six-acre section of Pool T in August 1952, killed 42 individuals (7 per acre) which ranged from 13.5 to 25.8 inches in length. Application of the Schnabel (1938) method of estimation gave an approximation of 8,647 pike for Pool C or about 12.4 individuals 14 inches or more in length for each of the 700 acres. In 1941, Pool M yielded 2,497 individuals mostly between 12 and 24 inches in length, or approximately 2 per acre. The greatest part of these fish was netted just below the spill of Pool C into the headwater marshes of Pool M.

Application of the DeLury (1947) method of population estimation to pike trapping data for 1941 (records from C. S. Johnson, Quarterly Narrative Report, May-June, 1941) provided the following approximations of standing crops: In Pools I and F, 2.3 per acre; in I, F, and J combined, 1.3 per acre. However, 2.1 fish per acre were removed from these waters while the data were being gathered and the last sets of the nets were still yielding fish. It is rather certain, therefore, that these estimates are sub-

stantially smaller than the actual populations, which are more accurately represented by the value previously given for Pool I.

The foregoing ranges of population density for pike on the Seney Refuge resemble those obtained by netting comparable gamefish waters in Minnesota (Moyle, Kuehn, and Burrows, 1950); they found 6.9 pounds per acre with a range from 0.0 to 42.5.

It appears that the standing population of pike 14 inches and greater in length may be estimated to have averaged about 10 per acre during the term of this study. If this is so, the total number of such fish present each year would approximate 60,000.

GROWTH—In the waters of the Seney Refuge, many pike attain the length of 14 inches during the second growth season. Average total lengths in inches for 460 individuals, collected in July through September 1941, according to number of annuli on their scales follow (the number of specimens for each average is given in parentheses): 0, 3.9 (215); I, 11.9 (74); II, 18.1 (107); III, 20.2 (51); IV, 24.8 (14); V, 24.5 (7); VI, 29.1 (1); VII, 25.4 (1). Obviously incomplete annuli were regarded as false and not counted in assessment of the foregoing (Williams, 1955).

FOOD—The generally piscivorous habit which is commonly associated with pike (documented by Solman, 1945: 161) is substantiated by the data in Table 1. Fish comprised about two-thirds of the food contained in stomachs of specimens collected by angling and netting and occurred in about half of all the specimens examined. Crayfish were next most abundant in volume (about one-fifth of the mass) and were present about as often as fish. There was no great difference in materials ingested in the two periods of sampling, 1941–43 and 1950–52.

The results of this detailed study supported the general findings of Refuge personnel who opened most of the 1,472 fish netted in May-June 1940, and found that fish, crayfish, and insects were the most common foods but that no waterfowl were present in the stomachs. The general consensus was that most feeding was done by pike in daylight hours and that the fish is essentially diurnal in its activity. This opinion is supported by Eddy (1954) and by the failure to catch pike on the Refuge by hook-and-line after the onset of darkness.

Ducklings were encountered in less than one per cent of individuals 14 inches long or longer which contained food as compared to a corresponding percentage of 4.8 calculated from the data of Solman (1945). Bajkov and Shortt (1939) and Ross (1940) en-

TABLE 1.—FOOD OF 1841 PIKE, 12 INCHES OR MORE IN LENGTH, 1941–43 AND 1950–52, IN WATERS OF THE SENEY REFUGE, MICHIGAN, BY ANGLING AND NETTING[1]

Food item	Percentage frequency of occurrence		Percentage composition by volume	
	1941–43	1950–52	1941–42	1952
Mammals	....	5.6	0.3	4.7
Birds	0.3	....	2.1	....
Frogs	2.1	6.4	2.2	5.9
Sport fish	20.2	25.6	36.0	35.7
Forage fish	31.5	8.0	33.0	28.9
Fish remains	0.2	16.8	0.5	0.8
Crayfish	42.9	49.6	23.1	21.4
Insects	11.6	8.0	1.8	0.1
Mollusks	0.9	1.6	0.1	0.1
Leeches	15.0	4.8	0.9	2.5
Number of pike (all of which contained food)	1254	125	378	84

[1] Annotated list of food items giving numbers of individuals eaten and other information. MAMMALS: *Microtus p. pennsylvanicus*, 7 individuals; remains, 1 individual. BIRDS: *Tringa flavipes*, 1; *Anas p. platyrhynchos*, 1; *Anas* sp., 2. FROGS: *Rana clamitans*, 5; *Rana pipiens*, 2; *Rana* sp., tadpoles, 17, adults, 18. SPORT FISH: *Ameiurus n. nebulosus*, 198; *Esox lucius*, 40; *Lepomis gibbosus*, 102; *Lepomis* sp., 5; *Perca flavescens*, 18. FORAGE FISH: *Catostomus c. commersoni*, 15; *Pimephales p. promelas*, 295; *Notemigonus crysoleucas auratus*, 83; Cyprinidae, 368; *Umbra limi*, 36; *Chrosomus eos*, 39; *Notropis h. heterolepis*, 9; *Poecilichthys exilis*, 38; *Eucalia inconstans*, 81. FISH REMAINS: 57 individuals. CRAYFISH: *Cambarus robustus*, 46; *Cambarus d. diogenes*, 250; *Orconectes virilis*, 28; *Orconectes propinquus*, 10; Cambarinae, 702. INSECTS (Adults unless otherwise indicated): Ephemeroptera, 2; *Anax junius*, 4; Libellulidae nymph, 1; Anisoptera nymphs, 65; Zygoptera nymphs, 241; Trichoptera larvae, 15, pupae, 2; Dytiscidae, 2, larvae, 3; Gyrinidae, 1; Corixidae, 2; Gerridae, 8; Belostomatidae, 2; remains, 80. MOLLUSKS: Pelecypoda, 1; *Helisoma antrosum*, 8; *Campeloma* sp., 1; Gastropoda, 5. LEECHES: Hirudinea, 267. MISCELLANEOUS (Not included in Table 1): Fragments of higher plants, in 14 stomachs; fish eggs, 23; garter snake, *Thamnophis sirtalis*, 1; offal (stomach of *Esox lucius*) in 1 stomach.

countered values of 2.0 and 0.74 per cent respectively but apparently included in their calculations all fish regardless of size and whether or not they contained food (which would automatically make their values relatively lower than those given above). Interestingly, in Canadian waters muskrats were preyed upon by pike, but not at Seney in spite of its substantial population. An indication of the abundance of muskrats in the early years of this study at the Seney Refuge is seen in the yield of 17,000 rats to share-trappers there in the 1942 season. For the years 1944 through 1954, the annual catch of these mammals, however, has not exceeded 4,000.

INFLUENCE OF AVAILABILITY ON FOOD HABITS—Availability has a strong effect on the food eaten by pike. In early July 1941, Pool I was poisoned with rotenone. Small fish, mostly minnows and the Iowa darter, showed distress at the toxicant almost immediately on its application in any area, and pike were observed to feed very actively on these debilitated, erratically moving individuals. Examination of contents of the stomachs of 104 such pike showed them to be consistently gorged with small fish which composed 85 per cent of their food by volume, an increase for this category over the average food picture (Table 1). There is no reason to suspect that Pool I had a forage population sufficiently different from other refuge waters to account for this deviation in food habits and the increased availability by debilitation of the prey appears to be accountable. It may also be concluded that specimens thus obtained are unreliable for use in ordinary food studies. Data on these are not included in Table 1. In the poison series from Pool I, comparable percentages for frequency and volume respectively in each category were as follows: sport fish, 19.2 and 33.8; forage fish, 92.3 and 51.3; fish remains, 7.7 and 0.8; crayfish, 34.6 and 13.9; insects, 5.8 and trace; leeches, 8.7 and 0.2.

The influence of availability of food on pike feeding and the gluttonous propensities exhibited suggest strongly that if ducklings had been more available than they were on the Refuge, more would have been eaten.

PREDATORY CAPABILITY OF PIKE—Although most food organisms consumed were substantially smaller than predator pike themselves, fish ingested were sometimes more than half as long as the feeding individual (Table 2). Frequently a portion of the tail of such prey was seen still protruding from mouth of the captor. The anterior end of the food specimen was variously digested and ranged from superficial integumentary penetration to disarticulation and partial solution of the head bones. Actual length measurements of entire food items or replications by comparison with preserved whole individuals of the same species gave a measure of the predatory capability of pike (Table 2).

TABLE 2.—SIZES, IN MILLIMETERS, OF SOME FISH EATEN BY NORTHERN PIKE WHICH AVERAGED 20 INCHES IN TOTAL LENGTH, SENEY REFUGE, 1941–43 and 1950–52

	Average total length	Range	Number of individuals
SPORT SPECIES			
Ameiurus n. nebulosus	123.9	70–184	23
Esox lucius	291.9	97–375	15
Lepomis gibbosus	45.0	30–127	100
Perca flavescens	75.2	25–142	10
FORAGE SPECIES			
Notemigonus c. auratus	62.7	38–102	46
Pimephales p. promelas	49.1	29– 86	208
Chrosomus eos	46.4	32– 67	21
Catostomus c. commersoni	124.7	45–406	15
Notropis h. heterolepis	48.1	38– 64	7
Umbra limi	72.6	45–105	27
Poecilichthys exilis	38.5	29– 68	41
Eucalia inconstans	42.9	26– 67	40
Cyprinidae	54.4	47– 57	5

Twelve pike in the 1941–43 series taken by angling and netting contained white suckers whose original size could be ascertained. These prey organisms ranged in total lengths from 0.11 to 0.52 of the like dimension of the pike which consumed them (average, 0.25). Fifteen pike in the same lots were cannibalistic and took others with a length relationship, ranging from 0.20 to 0.56 and averaging 0.43. Earlier a 13-pound, 28.5-inch specimen had been found which contained a 2-pound sucker and a 1-pound pike. There is also a record of a 27-inch individual which had a 1.5 pound, 21-inch pike in it (C. S. Johnson, Quarterly Narrative Report, August-October, 1940).

From the point of view of fishery management, the conclusion of Moyle, *et al.* (1950) for certain Minnesota waters that pike are the most valuable fish, seems to apply at the Seney Refuge. Although spawning stocks of

pumpkinseeds and perch were present in all pools, their numbers were not great. Furthermore, it seemed unlikely that overpopulation and stunting of these or other species (except possibly the brown bullhead) might occur in the presence of pike populations such as those present.

RELATION TO WATERFOWL—On the Seney Refuge young waterfowl of a size vulnerable to predation by pike are abroad for about three months each year, as disclosed by personal observations, Refuge records, and Beard (1953). In Canadian waters Solman (1945) estimated that the same period lasted for about 80 days. Extremes of the calendar interval concerned are in April and August, with specific dates varying according to weather of the year and bird species. At Seney, ducklings occurred in only 3 (0.2%) of 1,218 pike (14 inches in length or longer) taken during this interval.

To complement the information on the low incidence of pike predation on ducklings, many broods were observed for different lengths of time from blinds or by stalking. In all instances they were watched on water areas in which it could be assumed with certainty that pike were present. These broods were under close scrutiny for a total of 5,535 duckling minutes in May and June of 1942. The young were all small, less than one-quarter grown (mostly about fist-size), and could easily have been taken by the average 20-inch pike present. Kinds included black duck, mallard, ring-necked duck, American merganser, hooded merganser and Canada goose. Numbers in the broods ranged from 5 to 12. No evidence of pike predation was seen and no birds showed alarm. To the foregoing kinds may be added baldpate, blue-winged teal and wood duck, the young (and adults) of which were kept under rather intensive surveillance by Beard (1953) both in pools and adjacent beaver marshes with no indication of pike disturbing them.

That pike are not consistently a menace of young waterfowl was disclosed in two simple experiments. In one of these, a live downy mallard was tethered to a fly-fishing rod with 25 feet of monofilament 2× leader material. The living bird was then towed and guided over and through the water of a spill-pool. It was not attacked by pike, yet at this spot, 10 minutes before beginning the trial, a 25-inch pike had been hooked and released and within 15 minutes of the end of the experiment two additional specimens, 20 and 26 inches long (both with empty stomachs) had been caught. The fish were taken on a 5/8-ounce casting spoon "gold-plated" on both sides, carrying a treble hook, cast in the areas frequented by the tied bird, and retrieved within one foot or less of the water's surface.

In another experiment, 8 pike ranging from 19 to 26 inches in length were placed in a 3-by-8-foot hardware-cloth enclosure in a foot of water. Although the pike fed somewhat reticently on sunfishes and minnows offered them on three successive days, they did not take two downy mallards left in the enclosure for 12 hours on the fifth day of the series.

The 0.2 per cent incidence of waterfowl in pike food may be compared with the findings of Solman (1940 and 1941 manuscript reports to Ducks Unlimited, Winnipeg) in the Lower Saskatchewan Delta, Manitoba. As computed from Solman's data (*ibid.*), frequency of occurrence of ducklings was approximately 3.8 per cent (29 of 759 pike which had food in them and were 14 inches or longer contained ducklings). About 19 times as many pike in Manitoba waters contained young waterfowl as in the Seney area. This greater frequency may be due to the presence per unit of area of more ducklings, of more pike, of fewer buffer forage organisms, or to different interactions of these and other habitat variables. The protective role of abundant forage fishes of Seney and the apparently lesser number of birds and of pike certainly could account for the total difference. The average size of pike in both populations is much the same with the greatest numbers of individuals of avian predatory capacity falling between the lengths of 14 and 17 inches and ranging upward to 3 feet in length (but with individuals studied for food averaging about 20 inches).

In the Canadian waters studied for Ducks Unlimited (Solman, 1945), the loss of ducklings was estimated at one for each 1.4 acres of water or, 0.6 bird per acre) during the 39-day period from June 13 to July 21, 1941. Feeding experiments showed that, on the average, 0.43 per cent of the weight of duckling is digested per hour by pike (19 to 29.5 inches long) and that about 10 days is required for complete digestion! Since duck-

lings were found to be available to pike for about 80 days in the 1941 season it was considered possible that a pike might eat 8 ducklings during this period. Assuming no interval between feedings the loss of ducklings was estimated as follows (on tenuous ground): With a pike population estimated at 27 per acre, of which about one per cent was presumed to eat ducklings on eight occasions during the season, the calculated loss of ducklings amounted to about two ducklings per acre per season. This did not diverge greatly from the observed loss of 0.6 duckling per acre for 39 days (half of the season). The observed loss is, of course, smaller since it is unlikely that the total loss would show in a study of this kind. If the actual loss is between the observed and calculated figures, it might equal about one duckling per 0.6 acres (1.7 per acre) of this type of water area per person. If identical conditions are assumed for Seney, a loss of one duckling for each 0.6 acre of water per season, for an estimated 6,000 acres the loss would be some 10,000 ducklings. But, this is perhaps more ducklings than are produced annually on the area and since some young come all the way through the season, this cannot be the case. In some of the better-than-average brood areas of the Refuge, Beard (1953) reported a mean production of about three young (range, 1.7 to 4.6) per acre per year for 1947 through 1949.

CONTROL OF PIKE

The biological and economic risks of predator control and the oft-times undesirable, and sometimes unexpected, results of this practice are generally known among biologists. On the basis of present information on the Seney Refuge, certainly it would be unwise to instigate any wholesale decimation of pike. Yet much could be learned of value here and elsewhere by the conduct of a sound, long-range experimental program.

Some common methods commensurate with marsh- and water-bird production by which pike populations may be reduced are gill netting, seining, trapping, poisoning, dynamiting, and angling.

GILL NETTING—Gill netting as a means of removing pike was tried on the Refuge during 1940 (C. S. Johnson, Quarterly Narrative Report, May-July, 1940) and in this study in 1941. Several were taken but the abundant brown bullheads clogged the nets and required many man hours for their removal because the serrate pectoral spines of this catfish became entangled in the mesh. One three-and-a-quarter-hour set of 100 feet of a 3-inch-stretch-mesh gill net in a spill-pool yielded 8 pike and 47 bullheads (Collection L41: 627). Another set of this gear overnight in another plunge basin of the same kind took 11 pike and 118 bullheads (L41: 643) and required two man hours to clear the net of the catfish. Although most of the bullheads were living when the net was lifted, almost all of the pike were dead. The same fate was reported for practically all of 1,472 pike taken by this means in 1940 (C. S. Johnson, *op. cit.*).

SEINING—Seining is adaptable for pike removal in waters free from obstructions. Artificial impoundments such as most of those at Seney contain too many snags for this method to be used efficiently. In addition, seining under any circumstances would be most effective in reducing the numbers of small pike and would be least effective for individuals 20 inches and more in length which are the most serious menaces to waterfowl (Solman, 1945). Cost per pike taken in seining operations on the Refuge in 1941 was 4.8 cents (C. S. Johnson, Quarterly Narrative Report, May-July, 1941).

TRAPPING—Trapping with fykes or other shallow-water trap nets is about as satisfactory a means for taking pike as is gill netting. It has an advantage, in that most fish caught are in good condition for transferral to other waters—and pike are currently deemed very valuable as population controls in certain sport-fish complexes (Smith, 1941). However, individuals of certain sizes, depending on the mesh of the trap twine, tend to gill themselves, and others to injure themselves by ramming the sides of the net. More than a thousand specimens were taken in trap nets in the spring of 1941 for transplantation to state waters at an approximate cost of 57 cents per fish (C. S. Johnson, Quarterly Narrative Report, May-July, 1941).

Traps in the form of weirs have been shown to be effective for capturing pike (Carbine, 1942 and 1944). They are particularly applicable to small watercourses traversed by adults enroute to spawning grounds or by young on migration from the marshes in which they hatched. A makeshift mechanical weir was operated at the outfall

of Pool C into the head-marsh of Pool M and captured 266 individuals longer than 14 inches from June 9 through 19, 1943. Adaptation of electrical or electro-mechanical weirs such as used in sea lamprey control (Applegate, Smith, and Nielsen, 1952), almost certainly would have been as effective. The use of barriers to keep pike away from breeding and brood areas of waterfowl, as reported effective by Benson (1941) in Manitoba, would not be applicable here.

POISONING—Poisoning of waters with rotenone can be a successful method of killing pike as first suggested by E. E. Crawford (in Refuge Biological Report, manuscript, 1935). The method is not absolute, however, and is not at all selective in most situations. Approximate cost per pike in Pool I in 1941 by this means was 5.4 cents. Most of the individuals destroyed, however, were young of the year.

An opportunity for control peculiar to a development such as the Seney Refuge would be by induced winterkill. In some pools at this station winterkill could be brought about merely by shutting off the inflowing water at existing control structures. As indicated previously, winterkill has occurred naturally (*e.g.*, C. S. Johnson, Quarterly Narrative Report, May-July, 1938) in some of the isolated portions of certain of the impoundments and may at least partly account for apparent variations in pike population from pool to pool.

DYNAMITING—Selective use of explosives on concentrations of pike would doubtless kill individuals of the species. However, the two attempts which were made during the course of this study failed. In the summer of 1952, a submerged 2-stick and a 3-stick charge of dynamite were detonated successively in two borrow-pits of Pool A in Unit II. Pike were presumably present in these waters when the detonations took place but only small minnows (mostly golden shiners and blacknose shiners) were seen killed and were dipped from the water. The same two depressions were then poisoned with rotenone. No pike appeared in this trial either. Perhaps none were present or else they fled the disturbances. The area was not isolated from the main pool.

ANGLING—Angling is another method that has been used for removing pike as well as collecting them for study. The means has been both popular with the public and has afforded considerable recreational benefit while in progress. Certain waters of the Seney Refuge were opened for sport fishing in an experimental control program during parts of the years 1941 through 1944 and such fishing for this species has been adopted as general policy since then. In the four years mentioned, nearly 3,000 anglers took almost 4,500 pike 14 or more inches in length. The most common form of fishing was bait-casting with treble-hook spoons in the daytime from the dykes.

Several things favor the use of angling on a permit system for pike control, at least in situations such as that at the Refuge: (1) the fishery is selective for the sizes of pike which constitute the greatest potential hazard for waterfowl; (2) sound recreational and educational values are obtained; (3) the angling pressure can be controlled and shifted from pool to pool as desired; (4) it is possible that an index to the level of the pike population may be developed from creel census returns and used as a basis for shifting or intensifying the rod pressure.

Unrestricted use of angling as a control, however, might be a greater menace to waterfowl production than the pike would be if left alone. Human disturbance of ducks during the rearing and post-nuptial moult periods has been shown to cause them to desert parts of the refuge pool and marsh areas (Beard, 1953). However, the use of a permit system for confinement of public travel and fishing activities to regions adjacent to the deepest open waters (along selected dykes) has afforded control where desired along with recreational use. Such regulated exploitation of the fishery resource has apparently conflicted very little with the best psychological interests of the birds during the period critical for them.

An inventory of anglers' catches was kept for the fishing seasons on the Refuge during the years 1941 through 1944 (Table 3). In all, 1,080 parties composed of 2,951 fishermen and an uncounted number of accompanying visitors used the resource. The anglers put in 9,707 recorded hours of fishing for pike in addition to much unlisted time for perch and bullheads. The total catch of legal-sized pike (14 inches) was 4,714 and gave an average return of 0.46 fish per hour (equivalent to a 20-inch pike for every two hours of fishing; actual size range of those caught was 14 to 40.5 inches).

TABLE 3.—SUMMARY OF CREEL CENSUS ON PIKE FISHING, SENEY REFUGE, 1941–1944

	Sept. 12–Dec. 17 1941	May 15–July 31 1942	May 23–July 31 1943	May 15–Aug. 15 1944
Number of parties	100	442	342	196
Number of fishermen..	235	1238	866	552
Keeper pike caught...	531	1426	2107	384
Average length of legal-sized fish (inches)...	19.6	19.9	20.7	20.9
Small fish caught.....	70	62	201	16
Parties that caught no fish.....	20	143	50	56
Fisherman hours.....	733.0	4287.8	3598.7	1087.5
Number of pike per fisherman hour	0.72	0.33	0.59	0.35

That both population density and angler savvy are related to fishing success was shown in the Seney records as elsewhere (Lagler and de Roth, 1953). In four successive years, 1941–1944, the catch per hour for legal pike ran successively 0.72, 0.33, 0.59, 0.35. In the first year the fishing was done mostly by local residents. Sites knowingly chosen were widely distributed and were the natural areas of concentration for pike. In 1942, when the return dropped to 0.33 legal fish per angler hour tourists and others joined in the public fishing which was confined principally to the northern and eastern parts of Pools C, E, and F. In 1943 it was chiefly carried out in more recently flooded pools of Unit II (M, C, and A) and the take increased. In 1944, A, B, D, and the southern part of E, all in Unit I, bore the load, and the catch per unit of effort fell again. However, the general impressions relative to differences in population density of pike obtained from personal netting, angling, and survey of the pools were substantiated by the creel returns.

SUMMARY AND CONCLUSIONS

Habitat favorable to pike and to waterfowl, as well as to a wide variety of other marsh and aquatic organisms, was created by flooding portions of the lowlands at the Seney National Wildlife Refuge in the years 1936 through 1942.

Within five years of inundation pike appeared in all 19 of the refuge pools in numbers up to at least 22 per acre (exclusive of young-of-the-year) and averaged between 19 and 20 inches in length (based on gill-net, trap, and hook-and-line samples of upwards of 6,700 individuals from all pools).

Fish and crayfish were by far the most important and most consistently eaten food of 1,841 pike 12 inches or more in length taken by angling or netting. Waterfowl were present in only 3 of 1,218 pike 14 inches long or longer which were collected during the 90-day waterfowl brooding season (percentage frequency of ducklings in this lot of pike was about 0.2). Pike were profoundly influenced in their feeding by availability of small forage minnows, on which they gorged themselves during a control experiment with rotenone. However, they spurned tethered ducklings in natural waters and free-swimming individuals in an experimental enclosure when the birds were offered for relatively brief periods.

The basis for pike control on the Seney Refuge rests upon the following premise, in part at least warranted by the data in hand: elimination of each 500 pike "meals" may be expected to result in the saving of the life of a duckling. Unfortunately the frequency with which pike feed is not known so that the "meals" cannot be translated accurately into numbers of pike to be removed. Experiments on periodicity of feeding, for example those of Solman (1945), are too tenuous to be acceptable for use in extrapolation. If, however, each of the pike on the Seney Refuge large enough to eat a duckling, had a meal per day, and if there are as many as 60,000 such fish on the area, some 60,000 meals are eaten daily. Ducklings are available to pike for about 90 days each year on the Refuge. The duck population is thus exposed, in this hypothesis, to a predation pressure of 5,400,000 pike-meal-units per season. The observed incidence of approximately one duckling in each 500 pike opened (of sizes large enough to eat ducklings and all containing some food) might be considered as an incidence of one such bird per 500 meals. This could mean an annual duckling mortality on the area of 10,800.

Of several means of control tried on the Refuge, angling had the widest human appeal and appeared to cost least per fish removed. Unless properly restricted, however, it was recognized that angler activity might interfere with waterfowl production as much or more than the pike themselves, by disturbing the parent birds.

REFERENCES CITED

APPLEGATE, V. C., B. R. SMITH, and W. L. NIELSEN. 1952. Use of electricity in the control of sea lampreys: electromechanical weirs and traps and electrical barriers. U. S. Fish and Wildlife Serv., Spec. Sci. Rept.: Fisheries, 92, 52 pp.

BAJKOV, A. D., and A. H. SHORTT. 1939. Northern pike (jackfish) as predator on waterfowl and muskrats. Publ. Ducks Unlimited (Winnipeg). (Original not seen.)

BEARD, E. B. 1953. The importance of beaver in waterfowl management at the Seney National Wildlife Refuge. Jour. Wildl. Mgt., **17**: 398–436.

BENSON, R. 1941. They'll be flying high . . . . a rosy report from duckland. Mo. Wildlife, **3**(10): 8–9.

BERQUIST, S. G. 1936. The Pleistocene history of the Tahquamenon and Manistique drainage region of the Northern Peninsula of Michigan. Geological Survey Division, Michigan Dept. of Conservation Publ. 40, Geol. Ser. **34**: 17–137.

CARBINE, W. F. 1942. Observations on the life history of the northern pike, *Esox lucius* L., in Houghton Lake, Michigan. Trans. Am. Fish. Soc., **71**: 149–164.

———. 1944. Egg production of the northern pike, *Esox lucius* L., and the percentage survival of eggs and young on the spawning grounds. Pap. Mich. Acad. Sci., Arts, and Lett., **29**: 123–137.

———. 1945. Growth potential of the northern pike (*Esox lucius*). Pap. Mich. Acad. Sci., Arts, and Lett., **30**: 205–220.

DELURY, D. B. 1947. On the estimation of biological populations. Biometrics, **3**: 145–167.

EDDY, S. 1954. Pike—or pickerel? Minn. Cons. Volunteer, **17**(99): 1–8.

LAGLER, K. F., and G. C. DEROTH. 1953. Populations and yield to anglers in a fishery for largemouth bass, *Micropterus salmoides* (Lacépède). Pap. Mich. Acad. Sci., Arts, and Lett., **38**: 235–253.

MOYLE, J. B., J. H. KUEHN, and C. R. BURROWS. 1950. Fish-population and catch data from Minnesota lakes. Trans. Am. Fish. Soc., **78**: 163–175.

ROSS, D. A. 1940. Jackfish investigation, 1940, Athabaska Delta, Alberta. Publ. Ducks Unlimited (Winnipeg). (Original not seen).

SCOTT, I. D. 1920. Inland lakes of Michigan. Mich. Geol. and Biol. Surv., Publ. 30, Geol. Ser. **25**, 383 pp.

SCHNABEL, Z. E. 1938. The estimation of the total fish population of a lake. Amer. Math. Monthly, **45**(6): 348–352.

SMITH, L. L., JR. 1941. The northern pike, its past and future. Minn. Cons. Volunteer, **3**(15): 1–5.

SOLMAN, V. E. F. 1945. The ecological relations of pike, *Esox lucius* L., and waterfowl. Ecology, **26**: 157–170.

WILLIAMS, J. E. 1955. Determination of age from the scales of northern pike (*Esox lucius* L.). 185 pp., 35 figs. Univ. Mich. Ph.D. Thesis on deposit in Univ. Mich. Libraries and on microfilm in Library of Congress.

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A FOOD STUDY OF THE FLORIDA BOBWHITE

Colinus virginianus floridanus (Coues) [1]

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Numerous food studies of the bobwhite quail have been made in the southeastern states, but few have been made in Florida. Judd (1905) studied crops from thirty-nine birds from western Florida. Handley (Stoddard 1936) included fifteen birds from the region of Gainesville, Florida, but the rest of his data were obtained from further north. Laessle (1945) analyzed 200 crops collected through the year from seven counties in peninsular Florida but these were from a variety of habitats, not including the extensive southern Florida "flatwoods" which have proven to be excellent quail hunting areas.

This study is based principally on the detailed analysis of 375 crops taken at monthly intervals from February 1946 through January 1949 on a 62,000-acre wildlife management area in Charlotte County, Florida. This area is predominantly cut-over southern slash-pine (*Pinus elliottii densa*) (*P. caribaea*),[2] with a ground cover dominated by saw-palmetto (*Serenoa repens*) and wiregrass (*Aristida stricta*) (Fig. 1). Less than one per cent of this area is composed of scattered stands of cabbage-palm (*Sabal palmetto*), live-oak (*Quercus virginiana*) and swamp red-bay (*Persea palustris*) (*Tamala pubescens*). Frequent wet prairies and temporary, shallow ponds occupy areas slightly lower than the general level of the "flatwoods." Vegetationally similar areas (Fig. 2) are extensive in southern Florida and are described by Davis (1943). These areas, when still covered by native vegetation, should supply quail with a diet similar to that observed in this study.

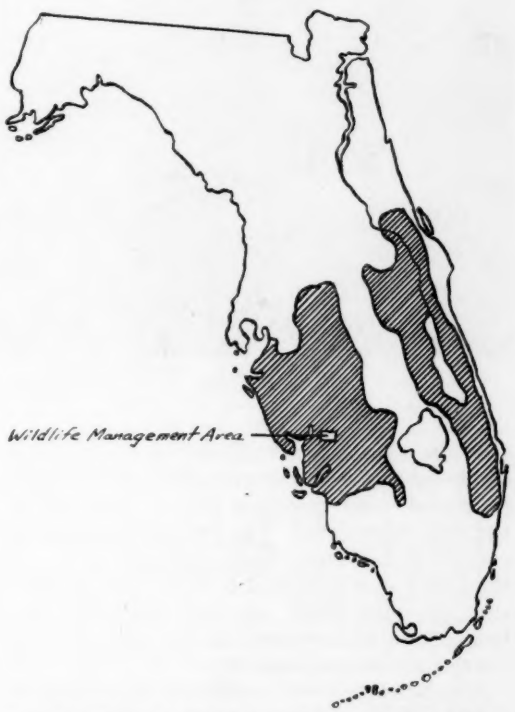

FIG. 2. Map of peninsular Florida. Crosshatched areas are vegetationally similar to the wildlife management area shown as a white rectangle.

Frequent fires and grazing by cattle have been the rule over most of this region and in recent years there has been a great increase in improved pastures accompanied by drainage and clearing of much of the native vegetation. Such improved pastures are not included in the wildlife management area upon which this study is based.

[1] Publication of this paper was financed by the Florida Game and Fresh Water Fish Commission.

[2] Where possible plant names follow Thorne (1954). Where these differ from those of Small's Manual of the Southeastern Flora (1933), the Manual name is given as a synonym.

FIG. 1. Typical Charlotte County "flatwoods".

While the average rainfall is about fifty inches per year, its distribution is seasonal, nearly seventy per cent falling from June through September. The remainder is fairly evenly distributed, but droughts such as the two-and-a-half-inch total from February through May 1945, are not unusual. Very heavy rains accompanying or associated with hurricanes occur regularly in the early fall.

The temperature is subtropical, averaging about 73°F. yearly. Killing frosts are infrequent, only four occurring over a thirteen-year period. Most of the flora is common to the southeastern coastal plain but a few tropical elements such as the fruits of woevine (*Cassytha filiformis*), bustic (*Dipholus salicifolia*), and myrsine (*Rapanea quayanensis*) turned up as items in the quail diet.

METHODS

While an attempt was made to obtain from ten to fifteen crops per month, a minimum of only four was taken in June 1947, and a maximum of sixteen was obtained in July 1946. Since it was found that the contents of the crops of all birds of a covey were essentially similar, it was general practice to take only one bird per covey. Only eight of the crops examined were from chicks or very young juveniles weighing less than 100 grams. Most birds were obtained in mid-morning or late in the afternoon at which times their crops were more apt to contain considerable food. While a few crops were nearly empty, their average air-dried weight was over two grams. Particular efforts were made to collect birds from various parts of the study area each month.

It was decided that an analysis based on air-dried weight gave a more accurate picture of potential food value, but only after a "compressed" volume method was tried (Table 1). In the experimental volumetric method, air dried insects, fleshy fruits and green vegetation were compressed to a very considerable degree in a calibrated vial. No attempt was made to compensate for air space between large and rigid seed or fruits. In the gravimetric method, a Cenco triple beam balance calibrated to .01 gram was used.

TABLE 1.—COMPARISON OF AIR DRIED WEIGHTS AND AIR DRIED VOLUMES OF SOME IMPORTANT FOOD ITEMS FOUND IN QUAIL CROPS

Item	Grams	C.C.
Rhizopogon sp.* Puffball fungus.....	116.2	100
Scleria muhlenbergii.....	64.5	100
S. verticillata.....	73.0	100
Panicum spp. > 2 mm.	59.2	100
Paspalum spp. < 2 mm.	78.0	100
Myrica pumila.....	73.4	100
Green vegetation.....	73.3	100
Beetles (medium size).....	15.0	100
Grasshoppers (medium size).....	21.1	100

* The specific gravity of this item was no doubt increased by some sand content which was difficult to separate entirely from the viscous mass of *Rhizopogon*.

In preparing the gravimetric table for monthly consumption of the various foods: (1) the sums of the air-dried weights of each item were determined for all crops during one month; (2) these sums were then added to give a total weight for all food items for that period; (3) the ratio of the weight of each individual item sum (1 above) to the total weight (2 above) was then calculated as a percentage. Yearly percentages were calculated by adding the monthly percentages and dividing by twelve. The three-year averages are the sum of the yearly averages divided by three. No attempt was made to compensate for the fact that the number of crops was not equal in all months; nor in all years. Figure 3 shows the approximate monthly consumption of the twenty-three items totaling more than one per cent over the three-year period.

Most of the plant determinations were made from comparisons with a seed and fruit collection made by the senior author over a period of eighteen years. Mr. Erdman West, Mycologist, University of Florida Agricultural Experiment Station, was particularly helpful in determining the puffball fungus (*Rhizopogon* sp.) which occurred as a viscid disintegrated mass in many of

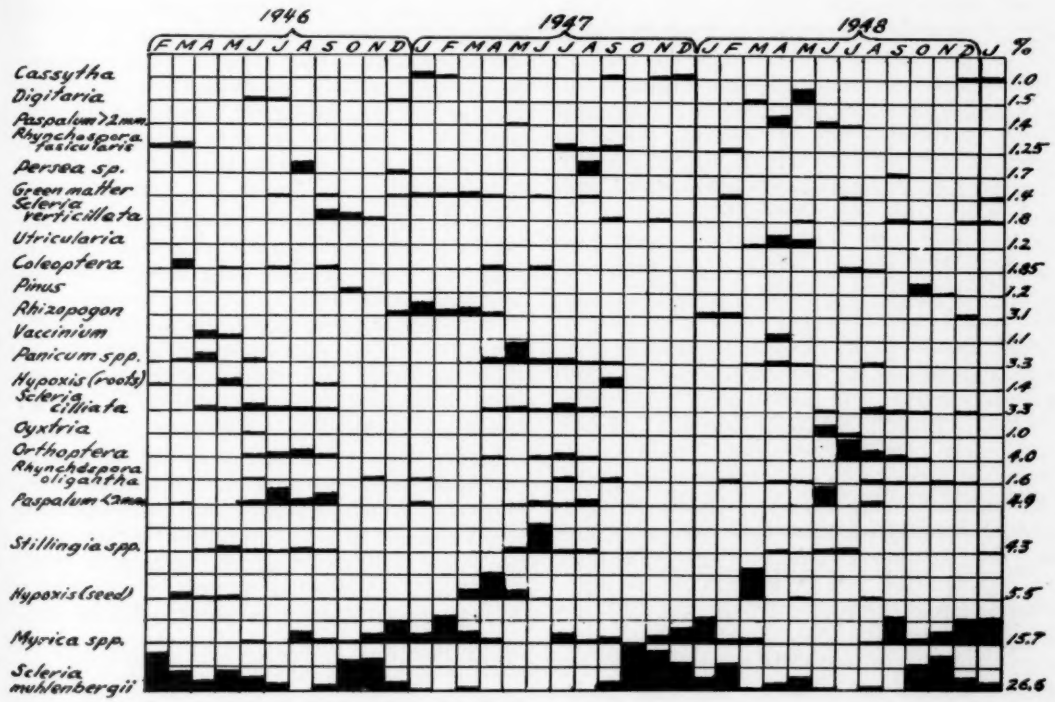

FIG. 3. Relative use of the twenty-three most utilized items for the three years, showing the approximate percentages consumed for each month. Each small square equals fifty per cent. The column at the right gives the average consumption for the three year period.

the winter crops. No attempt was made to carry the determinations of animal matter further than general groups such as grasshoppers, beetles, earthworms, etc., except where large numbers of what was obviously one species were encountered. It was thought impractical to carry many of the plant determinations in such large and difficult genera as *Panicum* and *Paspalum* to species.

DISCUSSION

It became evident very early in this study that the quail food habitats of this region were quite different from any of those hitherto reported. The great consumption of *Scleria muhlenbergii*, known locally as slough-grass, was most unusual. As the study progressed, it became apparent that the two principal foods, slough-grass (26.64%) and wax-myrtle (15.66%) bore a nearly reciprocal relation to one another. When the consumption of these items is plotted by months for the three years (Fig. 4), a number of interesting facts are apparent. Wax-myrtle begins to be eaten in considerable quantities in the period between July and September during which time little slough-grass is consumed—it does not mature its achenes until September. During October and November its consumption averages about 75 per cent and the utilization of wax-myrtle falls rapidly. Then by December or January wax-myrtle again assumes a major role while the consumption of slough-grass falls rapidly. As the wax-myrtle is available from July through January, it appears that the quail exhibit a marked preference for slough-grass and only partake of wax-myrtle to a considerable degree after the slough-grass supply has been nearly depleted.

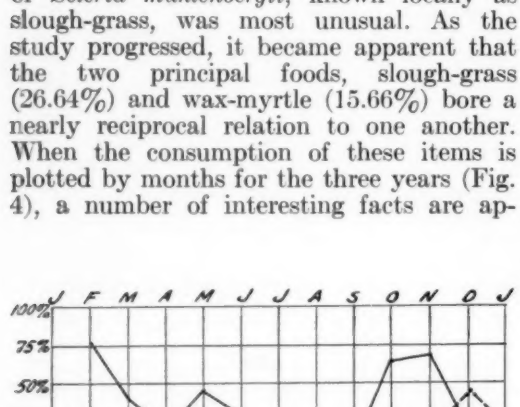

FIG. 4. The seasonal usage of slough-grass and wax-myrtle.

In further analysis of Fig. 4, it is worth noting that quadrat studies yielded the following data on slough-grass abundance: Fall, 1946—128 fruits/square yard; Fall, 1947—205 fruits/square yard; Fall, 1948—only 45 fruits/square yard. The quail populations according to bird dog census on the basis of 57,000 acres were: Fall, 1946—8,776 birds; Fall, 1947—1,455 birds. Because of the fact that these figures are based only on birds found by dogs and so do not consider those that are certainly missed even by the best of dogs, they are conservative to an unknown degree. Nevertheless, they are considered to be adequate for comparisons of year-to-year abundance of quail. While no census was made in the fall of 1945, general field observations as well as opinions of Charlotte County hunters indicate that the quail population was then comparatively low.

In correlating quail abundance and slough-grass yields, it may be generalized that a comparatively low quail population and excellent slough-grass crop in the fall of 1945 resulted in a good carry-over and heavy consumption of slough-grass in the spring of 1946; that an exceptionally high quail population and average slough-grass yield in the fall of 1946 resulted in poor carry-over and low utilization in the spring of 1947; and that a low quail population and high slough-grass abundance in the fall of 1947 resulted in a fairly high carry-over and utilization in the spring of 1948.

It is realized that other factors such as the large flocks of mourning doves, *Zenaidura macroura* (L.) observed on the area in the fall of 1946 may have considerably re-

TABLE 2.—NUTRITIONAL ANALYSIS OF WAX-MYRTLE (*Myrica* SPP.), SLOUGH-GRASS (*Scleria muhlenbergii*) AND A THEORETICALLY "IDEAL" QUAIL DIET

	Moisture	Crude Protein	Fat	Crude Fiber	N. free extract	Ash	Ca.	P.
Wax-myrtle.....(1)	6.21	2.76	17.58	4.53	12.62	2.26	.018	.305
Slough-grass.....(1)	10.50	16.15	15.90	13.05	7.4	37.0	.52	.4
"Ideal" Quail Diet..(2)	8.9	14.6	7.1	7.8	59.0	2.8	.51	.32

(1) Analyses by the State Chemist of the Florida Department of Agriculture. Analysis was made of only the waxy meat of the fruit but to permit the most realistic approximation of the value to quail of each unit weight of fruit the percentages are adjusted to include the weight of the "pit", which usually passes entire through the digestive tract.

(2) Percentage composition of a combination of various wild feedstuffs in proportions approximating the selection made by captive quail. Nestler *et al.* (1945).

duced the slough-grass supply.[3]

The apparent preference by quail for slough-grass over wax-myrtle is of particular interest in the light of the nutritional analyses presented in Table 2. It will be noted that nutritional analysis of slough-grass quite closely approaches the proportions of the all important nutrients, protein, phosphorous and calcium in the "ideal" quail diet.

While contrary to the opinion of Spinner and Bishop (1950) that in no case could utilization be correlated with nutritive value as measured by proximate chemical compositions, this study definitely indicates that, where quail have an opportunity to choose, they will select those items better satisfying their nutritional needs.

The lack of balance in nutrients observed in wax-myrtle may well be the explanation of the markedly lower vitality observed during February 1947, when it was noticed that birds from numerous coveys were unable to fly again after their initial extended flight when flushed. This is the only time when such a condition was noticed. It is also the only period in which the main food was wax-myrtle and during which practically no slough-grass was consumed. Two quail trapped at this time died in retaining pens and were preserved and sent to Dr. Glen van Ness, Research Veterinarian at the Florida Agricultural Experiment Station, Gainesville, Florida. He reported that these birds were probably suffering from a calcium or other nutritional deficiency—at least they resembled chickens so affected. The reader is referred again to the extremely low protein and calcium content of the utilizable portion of wax-myrtle. It is also worthy of note here that Nestler *et al.* (1945) working with captive quail, found the highest mortality and most serious instances of cannibalism among birds subsisting principally on wax-myrtle.

The seasonal occurrence of some of the more important items, other than slough-grass and wax-myrtle, based on three-year averages except where otherwise noted, were: puffball fungus, 31.5 per cent in January 1946; Southern slash-pine, 29.5 per cent in October 1948; *Panicum* spp., 14 and 16 per cent in April and May respectively; *Paspalum* spp. 2mm. (principally *P. longipedunculatum*), 22.5 per cent in June; *Scleria cilliata*, 8 per cent for June, July and August combined; *Hypoxis* spp. (seed), 30.5 and 19.5 per cent in March and April respectively; *Hypoxis* spp. corm-like rootstocks, 7.5 and 7.0 per cent in May and September respectively (these were from birds obtained from about hog rootings); *Oxytria albiflora*, 24 per cent in June 1948; *Stillingia* spp. 10.0 and 13.5 per cent in May and June respectively; *Persea* sp. 19.5 per cent in August; *Cassytha filiformis*, 8 per cent in January; *Vaccinium myrsinites*, 10.5 per cent in April, *Utricularia subulata*, 23 and 14 per cent in April and May respectively of 1948; beetles, 8 per cent in March, due mainly to 19.5 per cent taken in March 1946, nearly all of which were a medium-sized scarabaeid, *Anomalepta semilivida* Lee.

[3] Subsequent observations showed that slough-grass totaled more than 95 per cent in the crops of the mourning doves collected on the management area October 21 and November 7, 1947; March 18, 1948; February 2, November 25 and December 20, 1949; and April 5, 1950.

(one bird contained 197 specimens); *Orthoptera*, mostly Melanoplus spp., 18.5 and 14.5 per cent in July and August respectively.

While an average sample of slightly more than ten quail per month is not felt to be adequate, larger extra-hunting season kills had to be held to a minimum to avoid public and administrative criticism. It does seem, however, that a reasonably accurate picture has been achieved for the more important items. It also seems reasonable that certain of the less important items such as *Utricularia* consumed only in April and May 1948 and the great quantity of the quite rare beetle *Anomalopta semilivida* occurring only in March 1946, was due to peculiar combinations of weather, fire, and unknown biological circumstances which occasionally occur and that such irregularities in feeding habits would show up regardless of the size of the sample.

Every other quail food study conducted in the southeastern states reported a quite high consumption of legumes. Yet, the most abundant legume in this study, *Desmodium triflorum* (*Sagotia triflora*), formed only 0.59 per cent of the total food. The poorly drained "flatwoods" of this area support, quantitatively, very few legumes, and these mainly on roads and formerly cultivated areas where drainage has been improved. The replacement of these high protein foods is apparently accomplished to a considerable extent by the high consumption of sloughgrass and by a quite high consumption of animal matter. The 9.27 per cent animal matter by air-dried weight would considerably exceed the 14.41 per cent volumetrically calculated animal matter total reported by Stoddard (1936) (See volumetric and gravimetric comparisons for insects, Table 1). Seasonal fluctuations in the insect populations are almost as marked in southern Florida as in regions much further north, but consumption of them here reached a peak in July while Stoddard (1936) found October to be the peak. This is reasonable in the light of the much earlier "spring" of southern Florida.

Following is listed in approximate phylogenetic order those food items forming less than one per cent of the total food found in the crops analyzed over the three-year study:

Plant material (seed or fruits unless otherwise noted):

Mushrooms, *Ophioglossum* sp. (sporophylls), *Pinus palustris* (*P. australis*), *Setaria* sp. (*Chaetochloa* sp.), *Digitaria serotina* (*Syntherisma serotina*), *Digitaria* sp. (*Syntherisma* sp.), *Axonopus compressus*, *Axonopus furcatus*, *Cyperus* sp. corms, *Eleocharis* sp. *Psilocarya nitens*, *Rhynchospora tracyi*, *R. baldwinii*, *R. intermedia*, *R. inundata*, *R. globularis* (incl. *R. cymosa*), *R.* spp., *Scleria georgiana* (*S. gracilis*), *S. verticillata*, *S. hirtella*, *Xyris* sp., *Commelina* sp., *Aneilema nudiflora*, *Hymenocallis* sp., *Quercus* sp., *Polygonum* sp. (*Persicaria* sp.), *Chrysobalanus oblongifolius* (*Geobalanus oblongifolius*), *Cassia* spp. (mostly *aspera*) (*Chamaecrista* spp.), *Crotalaria* sp., *Sesbania macrocarpa* (*Sesban emerus*), *Tephrosia* sp. (*Cracca* sp.), *Galactia elliottii*, *G.* spp., *Desmodium canum* (*Meibomia cana*), *D.* spp. (*Meibomia* spp.), *Vicia* sp., *Oxalis* sp. (*Xanthoxalis* sp.) capsules, *Polygala grandiflora* (*Asemeia grandiflora*), *P. incarnata* (*Galypola incarnata*), *Croton* sp., *Cnidoscolus stimulosus* (*Bivonea stimulosa*), *Euphorbia* spp. (incl. *Chamaesyce* sp., *Tithymalopsis* sp.), *E. inundata* (*Galarhoeus inundata*), *Ilex glabra*, *Vitis* sp. (*Muscadinia* sp.), *Ampelopsis arborea*, *Parthenocissus quinquefolia*, *Melochia corchorifolia*, *Riedlea hirsuta*, *Piriqueta viridis*, *Viola septemloba* capsules, *Viola* spp. capsules, *Centella erecta* (*C. repanda*), *Oxypolis* sp., *Gaylussacia* sp. (*Decachaena* sp.), *Vaccinium myrsinites* (*Cyanococcus myrsinites*), *Rapanea quayanensis*, *Dipholis salicifolia*, *Asclepias* sp., *Evolvulus sericeus*, *Physalis* sp., *Heliotropum polyphyllum*, *Salvia lyrata*, *Gratiola pilosa* (*Tragiola pilosa*) capsules, *Lindernia anagallidea* (*Ilysanthes inequalis*) capsules, *Linaria canadensis* capsules, *Hedyotis* sp. (*Oldenlandia* sp.) capsules, *Richardia scabra*, *R. brasiliensis*, *Diodia teres* (*Diodella teres*), *Circium* sp.

Animal Food: Annelida (Earthworms), Phalangiidae (Daddy longlegs), Araneida (Spiders and egg cases), Myriopoda (Millipedes), Chilopoda (Centipedes), Isoptera (Termites), Orthoptera (Grasshoppers, crickets, etc. including roach ootheca and grasshopper eggs), Hemiptera (True bugs), Homoptera (*Kermes kingii* scale insect), Homoptera (Mealy Bugs), Lepidoptera (Moths, caterpillars), Coleoptera (Beetles—adults, larvae and pupae), Diptera (Flies—adults and pupae), Hymenoptera (Ants, mostly *Camponotus* sp., also sawfly pupae), Mollusca (Snails), Vertebrates (mostly *Bufo*

quercicus—oak toad, one *Acris gryllus*—cricket frog, and one unidentified frog).

SUMMARY AND CONCLUSION

A detailed examination was made of 375 crops of the Florida Bobwhite covering each month over a three-year period. A table showing the air dried, gravimetric percentages for the 23 more utilized items is presented showing the yearly variations and the three-year averages for these items.

The seasonal percentages of the more important items are presented and some factors which may contribute to yearly fluctuations are discussed. A list of items making up less than one per cent is presented principally because many of them have not previously been recorded as quail foods. Graphs showing the monthly consumption of the two most important foods, slough-grass (26.64%) and wax-myrtle (15.66%), show that late in each summer wax-myrtle is consumed in considerable amounts before slough-grass is utilized in appreciable amounts. During the fall, wax-myrtle consumption drops and slough-grass becomes a major item. By late fall or early winter, wax-myrtle becomes a major item and slough-grass diminishes in importance. This reciprocal relationship is believed to be evidence of a marked preference for slough-grass as the wax-myrtle was available throughout the slough-grass season. Analysis of the food value of these two items is presented showing slough-grass to have a much more balanced nutritional value, thus leading to the conclusion that when quail have access to a number of items, they tend to select items which best satisfy their nutritional requirements.

LITERATURE CITED

DAVIS, J. H. 1942. The natural features of southern Florida. Fla. Geol. Survey, Biol. Bull. No. 25, 311 pp.

JUDD, S. D. 1905. The bobwhite and other quails of the U. S. in their economic relations. U.S.D.A., Bur. Biol. Surv., Bull. 21, 66 pp.

LAESSLE, A. M. 1945. A study of quail food habits in peninsular Florida. Proc. Fla. Acad. Sci. **7**(2–3): 155–171.

NESTLER, R. B., W. W. BAILEY, A. C. MARTIN and H. E. MCCLURE. 1945. Value of wild feed stuffs for pen-reared bobwhite quail in winter. Jour. Wildl. Mgt. **9**: 115–120.

SMALL, J. K. 1933. Manual of the Southeastern Flora. Sci. Press Printing Co., Lancaster, Pa. 1554 pp.

SPINNER, G. P. and J. S. BISHOP. 1950. Chemical analysis of some wildlife foods in Connecticut. Jour. Wildl. Mgt. **14**: 175–180.

STODDARD, H. L. 1936. The bobwhite quail, its habits, preservation and increase. Charles Scribner's Sons, N. Y. 559 pp.

THORNE, R. F. 1954. The vascular plants of southwestern Georgia. Amer. Midl. Nat. **52**: 257–327.

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WILD TURKEY FOOD HABITS IN FLORIDA[1]

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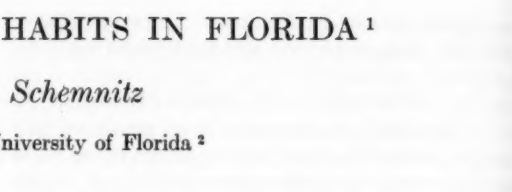
A knowledge of food habits of the wild turkey, *Meleagris gallopavo*, was considered of importance in evaluating the effect of various changes in agricultural practices on large areas of good turkey range in Florida. One of these changes involves the conversion of vast acreages of cut-over pine flatwoods grazed by scrub cattle to improved pastures of perennial grasses for use by improved cattle breeds. A knowledge of turkey food habits would be of some value in choosing suitable areas for restocking wild-trapped turkeys. The value of artificial turkey feeders in the program of maintaining and increasing the present high level of the turkey population estimated at 45,000 birds (Anon., 1950) also needed evaluation. Considerable work concerning turkey food habits has been accomplished in Virginia (Culbertson, 1948; Mosby and Handley, 1943; May *et al.* 1939) and Alabama (Wheeler, 1948; Good and Webb, 1940); but for Florida and other southern states this information is largely wanting.

Materials and Methods

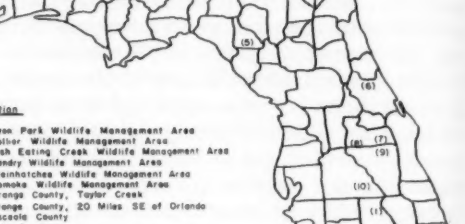
Thirty-two turkey crops were collected from hunters mainly by personnel of the Florida Game and Fresh Water Fish Commission on 10 areas (Figure 1) in the state from October, 1952, through February, 1953. Sixty lots of droppings were collected from 16 areas (Figure 2) representing every month of the year. A major portion of the droppings used in this study were collected in the vicinity of turkey feeders and under tree roosts.



Location

1. Avon Park Wildlife Management Area
2. Collier Wildlife Management Area
3. Fish Eating Creek Wildlife Management Area
4. Hendry Wildlife Management Area
5. Steinhatchee Wildlife Management Area
6. Tomoka Wildlife Management Area
7. Orange County, Taylor Creek
8. Orange County, 20 Miles SE of Orlando
9. Osceola County
10. Polk County

Fig 1— Localities From Which Crops Were Collected



No.	Location	No. of Lots of Droppings
1.	Avon Park, Highland County	2
2.	Big Cypress, Collier County	1
3.	Charlotte County	3
4.	Dade County	1
5.	Duval County	2
6.	East of Naples, Collier County	1
7.	Fish Eating Creek, Glades County	12
8.	Gulf Hammock, Levy County	2
9.	Lake Butler, Union, Baker, Columbia Counties	1
10.	Palm Beach County	8
11.	Peace River, Hardee County	3
12.	Polk-Osceola Breeding Grounds	14
13.	Richloam, Sumter County	1
14.	Steinhatchee, Dixie County	1
15.	Tomoka, Volusia County	7
16.	Volusia County Breeding Grounds	1
	Total	60

Fig. 2— Localities From Which Droppings Were Collected

Conventional procedures as described by Martin (1949) were followed in crop analysis. The dry droppings were crushed with a mortar and pestle, care being taken to avoid further crushing of already small fragments of seeds and insects. The dry method was more convenient than the technique of soaking in water for 24 hours to soften the droppings (Dalke *et al.* 1942). A visual estimate to the nearest 5 per cent was made of the quantities of each food item in the dropping.

A vegetation study was also undertaken to provide a basis for both a qualitative and

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a quantitative evaluation of samples of Florida turkey range. The eight major vegetation types recognized were: 1. Pine flatwoods woodland; 2. Pine island; 3. Oak-cabbage palm hammock forest; 4. Cypress ponds and swamp; 5. Wet prairie grassland; 6. Dry prairie grassland; 7. Mesophytic hammock forest; 8. Swamp forest. The vegetation of these types is described in more detail by Laessle (1942) and Davis (1943).

One-quarter-acre circular plots were employed in the vegetation analysis. These plots were located 5 chains apart along a compass line. At the center of each of these larger plots, a mil-acre sample quadrat (6.6 feet square) was also used for a more detailed survey of the ground cover.

Sampling of a vegetation type was considered adequate when a total of 10 sample plots were studied, and a 10 per cent increase in sample plot area resulted in less than a 10 per cent increase in new plant species, according to the method outlined by Oosting (1948). A total of 210 quarter-acre sample plots were thus examined. All plots were re-examined in the spring and summer following the initial winter examination with the exception of the dry prairie grassland, the mesophytic hammock forest, and the swamp forest. Analysis of these three types was delayed until after the large number of unknown plants had been collected and identified.

TABLE 1.—QUANTITY* AND FREQUENCY OF WINTER FOODS OF THE WILD TURKEY IN FLORIDA BASED ON 32 CROPS

Item of food and part used	Quantity		Frequency	
	Per cent	Rank	Per cent	Rank
Quercus—Acorns, fragments, and leaves	53.8	1	66	2
Q. virginiana (Live oak)	48.5	a	44	–
Q. laurifolia (Laurel oak)	3.2	b	28	–
Q. schumardii (Schumard oak)	0.6	c	3	–
Q. laevis (Turkey oak)	0.6	d	9	–
Q. cinerea (Willow oak)	0.4	f	7	–
Q. nigra (Water oak)	0.07	g	3	–
Q. chapmanii (Chapman oak)	0.02	h	3	–
Q. sp.	0.41	e	19	–
Pinus caribea (Slash pine)—seeds, wings, fragments	11.6	2	22	9
Paspalum spp.—seed	10.3	3	32	6
Sabal palmetto (cabbage palm)—seed	7.3	4	16	11
Pinus australis (Longleaf pine)—seeds, wings	2.8	5	12	12
Nyssa biflora (Black gum)—seed	2.1	6	34	5
Gynacantha nervosa Aeschnidae—dragonfly	1.63	7	16	11
Zea mays (Corn)—kernel	1.6	8	3	15
Xyris sp. (Yellow-eyed grass)—seed heads	0.9	9	12	12
Gramineae—grass, leaves	0.8	10	38	4
Cyperus sp. (Sweet rush)—tubers	0.6	11	19	10
Isoetes flaccida (Fern)—sporangia	0.56	12	19	10
Taxodium sp. (Cypress)—seed	0.56	13	19	10
Ilex glabra (Gallberry)—drupes, seeds	0.50	14	19	10
Panicum spp. (Panic grass)—seed	0.48	15	78	1

* Based on weight.

RESULTS AND DISCUSSION

CROP ANALYSIS—The winter foods of Florida turkeys revealed through this study are summarized in Table 1. On the basis of dry weight, the first ten items listed made up 92.8 per cent of the food consumed. Of a total of 114 foods eaten, only fourteen were present in amounts of 0.5 per cent or more. Only one of these, dragonflies, 1.6 per cent, was animal material. The relative amount of these insects was raised considerably by one crop taken on December 11, 1952, in Osceola County, south-central Florida. This crop, from an adult gobbler, contained 56 whole dragonflies (*Gynacantha nervosa*), which were the only food consumed. Pine and acorn mast together composed 68.2 per cent of all foods eaten. Of the seven species of acorns taken, live oak far outranked all others combined in total number, weight, and volume. Live oak acorns constituted 48.5 per cent of the total food intake and were the most important food of the Florida wild turkey found through this study. The total number of live oak acorns in a single crop varied from 1 to 137.5. Weights of these acorns in a single crop varied from 2 to 225 grams. Control by hunting and trapping of wild hogs, which consume large quantities of acorns and pine mast should tend to improve considerably the food supply picture for turkeys in many portions of Florida. Grass seeds of *Paspalum* spp. and *Panicum* spp., 10.8 per cent of the total (Table 1), were second only to mast in importance. The high rank of grass seeds in the turkey's diet accentuates the importance of the present trend toward improved pastures in increasing the turkey food supply. In many cases, these pastures are established on heavily cut over pine flatwood lands supporting rank growths of broomsedge and

wire grass which are little used by the turkeys for food.

The turkey foods made known through this investigation were also evaluated according to the volume-frequency index rank method developed by Baumgartner *et al.*, 1952 (Table 2). Percentage quantity and

TABLE 2.—VOLUME-FREQUENCY INDEX RANK OF PRINCIPAL WILD TURKEY WINTER FOODS IN FLORIDA BASED ON 32 CROPS

Food material	Quantity* rank	Frequency rank	Index** rank
1. *Quercus* spp.—acorns	1	2	1.5
2. *Paspalum* spp.—seed	3	6	4.5
3. *Pinus caribea* seed, wing	2	9	5.5
4. *Nyssa biflora* seed	6	5	5.5
5. Gramineae—grass leaves	10	4	7.0
6. *Sabal palmetto* seed	4	11	7.5
7. *Panicum* spp.—seed	15	1	8.0
8. *Pinus australis* seed	5	12	8.5
9. Odonata—Dragonflies	7	11	9.0
10. Orthoptera—Grasshoppers	16	3	9.5
11. *Xyris* sp. heads	9	12	10.5
12. *Cyperus* sp. tubers	11	10	10.5
13. *Isoetes flaccida* Fern spores	12	10	11.0
14. *Taxodium* sp. seed	13	10	11.5
15. *Zea mays* cracked	8	15	11.5
16. *Ilex glabra* drupe, seeds	14	10	12.0
17. *Myrica cerifera* (Wax myrtle) berries	20	8	14.0
18. Lepidoptera—Moths, larvae	18	10	14.0
19. Hymenoptera—Ants, wasps, sawflies	23	7	15.0
20. *Diodia* sp. (Buttonweed) leaves	17	14	15.5
21. *Myrica* sp.—berries	21	11	16.0
22. *Axonopus* spp. (Carpet grass) seed	28	4	16.0

* Based on weight.

** Index rank = $\frac{\text{(Quantity rank)} + \text{(Frequency rank)}}{2}$.

Baumgartner *et al.* (1952).

frequency measures are relatively difficult to interpret and evaluate clearly when considered separately. The third column of Table 2, the "index rank," was computed by adding the quantity rank and the frequency rank, and dividing the sum by two. The combination of the quantity and the frequency into one numerical expression of rank tends to present a clearer over-all view of the comparative importance of each food item.

According to the results of the analyses of 32 wild turkey crops, plant material contributed 97.1 per cent of the total food eaten. Animal material supplied only 2.9 per cent by weight of the total food, although 81 per cent of the crops contained some of this matter. This compares favorably with the findings of May *et al.* (1939), who reported 93.26 per cent vegetable material to 6.74 per cent animal material. The Mosby and Handley (1943) ratio was 94.74 per cent plant matter to 5.24 per cent animal matter. Culbertson (1948) in Virginia arrived at a plant : animal ratio of 94 : 6.

On the basis of the crops analyzed in this study, each turkey had consumed an average of 8 vegetable food items and 3 animal items. The number of vegetable items ranged from 3 to a maximum of 24. Animal matter varied from zero to 30 different items per crop. Unusual items consumed included the skin of a southern ribbon snake and small fragments of tin foil.

DROPPING ANALYSIS — The important foods found in the 2,775 droppings analyzed are listed in Table 3. Droppings are considered on a lot, rather than an individual dropping basis. Lots varied in size from 5 to 160 droppings. Each lot contained droppings collected from a single area on the same date.

As may be seen from Table 3, grass leaves had both the highest percentage of abundance and frequency of any one item in the dropping analyses, comprising one-fifth of the total food residue recognized and occurring in three-quarters of all the droppings. Altogether, grasses, including seeds and leaves, composed slightly more than half of the vegetable matter in the droppings. Taking into account the minor items, a total of 58 different kinds of plant and animal foods were identified in the 2,775 droppings. This total number compares with 65 food items occurring in 4,249 droppings as reported by Bailey *et al.* (1951) in West Virginia, and 71 food items observed in similar material by Wilson (1945) in Maryland. The largest number of food items recorded in a dropping analysis, 83, was reported for Missouri by Dalke *et al.* (1942) who based their results upon analyses of a total of 3,449 droppings. A larger variety of foods might have been recorded in this study had a greater number of droppings been collected during the summer and fall months. In general, dropping analyses indicate that there is relatively little variation in the total number of different foods consumed by wild turkeys in Florida, West Virginia, and Maryland.

TABLE 3.—PER CENT VOLUME* AND FREQUENCY OF OCCURRENCE OF IMPORTANT ANNUAL FOODS FOUND IN 2,775 DROPPINGS

Food	Volume		Occurrence	
	Per cent	Rank	Per cent	Rank
VEGETABLE:				
Gramineae—grass leaves	21.0	1	75	1
Paspalum spp. seed	14.0	2	45	8
Panicum spp. seed	10.0	3	68	2
Quercus spp. Acorn fragments	9.4	4	53	4
Ilex opaca seed	9.0	5	42	9
Zea mays fragments	6.5	6	49	7
Myrica sp. seed	6.0	7	50	6
Axonopus sp. seeds	5.0	8	33	10
Digitaria sp. (Finger grass) seeds	3.0	9	15	14
Sabal palmetto seed	2.5	10	22	11
Pinus sp. seed fragments	2.0	11	17	13
Taxodium sp. seed	1.5	12	20	12
Rubus sp. (Blackberry) seed	1.0	13	10	16
Rapanea sp. seed	1.0	14	7	18
Smilax sp. (Greenbrier) seed	1.0	15	10	16
****Physalis** sp. (Ground cherry) seed	0.7	16	7	18
****Portulaca** sp. (Portulaca) seed	0.5	17	3	19
Rynchospora sp. (Beakrush) seed	0.5	18	12	15
Nyssa biflora seed	0.3	19	20	12
Xyris sp. head fragments	0.2	18	9	17
Total Per cent	95.1			
ANIMAL:				
Coleoptera—beetles	1.5	12	63	3
Orthoptera—grasshoppers, crickets	1.4	13	52	5
Total Per cent	2.9			
Miscellaneous leaves	0.7	—	5	—
Miscellaneous plant fragments	1.2	—	20	—
Total Per cent	1.9			
Grand Total Per cent	99.9			

* Volume determined by visual estimate.
** Foods not present in crops analyzed.

When compared upon a seasonal basis (Table 4) it may be seen that important winter foods are grass leaves, acorns, wax myrtle fruits, gallberries, and the seeds of both panic grass and carpet grass. Together these items comprised 71 per cent of all foods eaten. In the spring, grass leaves, gallberries, and panic grass seeds maintained their importance. Use of corn and paspalum grasses increased while acorns, carpet grass seed, and wax myrtle consumption decreased.

Results of the analysis of droppings for the summer and fall, although based on a relatively small sample, show a pronounced increase in the use of paspalum grass seeds during the summer. In the fall, acorns and pine mast become available and appear in considerable amounts in the droppings.

TABLE 4.—SEASONAL VOLUME* OF MAJOR TURKEY FOODS BASED ON 2,775 DROPPINGS

Food	19 Lots Winter (%)	28 Lots Spring (%)	8 Lots Summer (%)	5 Lots Fall (%)
VEGETABLE:				
Axonopus sp. seed	7	2	4	7
Digitaria spp. seed	1	2	11	–
Panicum spp. seed	7	10	17	9
Paspalum spp. seed	5	6	46	45
Zea mays fragments	6	9	2	–
Gramineae—grass leaves	18	30	3	14
Ilex opaca seed	13	10	–	1
Myrica sp. seed	10	5	1	–
Pinus sp. seed	4	trace	–	6
Quercus spp. acorns	16	7	1	10
Sabal palmetto seed	13	10	–	1
Taxodium sp. seed	3	2	1	–
Nyssa biflora seed	1	trace	1	–
Smilax sp. seed	3	–	–	0
Rapanea sp. seed	0	2	0	0
Rubus sp. seed	0	2	0	0
Rynchospora sp. seed	1	–	–	–
Physalis sp. seed	0	–	1	0
Scleria sp. (Nut rush) seed	–	1	0	0
Xyris sp.	1	–	0	0
ANIMAL:				
Coleoptera—beetles	–	2	–	2
Orthoptera—grasshopper	–	2	–	–
Miscellaneous leaves	–	1	0	0

Legend: trace = items eaten 0.1 to 1 per cent
– = items eaten less than 0.1 per cent
0 = items not found during the season
* Volume determined by visual estimate.

While some foods show considerable seasonal fluctuation in consumption, others such as cypress seed and cabbage palm berries are eaten in consistently small amounts throughout the year.

It is interesting to note variations in the seasonal use of corn. In most cases the only corn available to the turkeys was at the feeders. During the fall when native foods such as acorns and pine mast are abundant, very little corn is consumed. The use of corn increases considerable during the winter and spring. Corn use decreases during the summer as the hen turkeys begin incubating and raising their broods, and the grass seed supply increases. This seasonal variation correlates well with the use of corn in turkey feeders as observed by Mr. Fred W. Stanberry, Wildlife Biologist, Florida Game and Fresh Water Fish Commission. Data presented in Table 4 suggest that the use of corn in turkey feeders is important in supplementing the natural food supply, es-

pecially during the winter and spring.

On an annual basis, 96.4 per cent of all food material found in droppings was vegetable matter, while 3.6 per cent was animal material. This compares favorably with observations in West Virginia (Bailey *et al.* 1951), which also gave a high annual percentage, 98.4, for vegetable material. Although composing only a small portion of the total food volume, some insect material occurred in 87 per cent of the droppings analyzed.

VEGETATION STUDY—Detailed vegetation analysis is a long-term project entailing many years of research and numerous repetitions of examinations. On the basis of this relatively extensive short-term study, only general conclusions as to seasonal fluctuations of the vegetation can be made.

Grasses, important foods found in the dropping and crop analyses, occurred in nearly every significant vegetation type. As the seasons progressed from winter to spring, panic grasses decreased in importance in most types while carpet grass increased. The seed crop of carpet grass was more abundant in summer than in either the winter or spring. Paspalum grass seeds seem to be a preferred food, since it is heavily eaten by turkeys in spite of being available in only small amounts. Its importance is further emphasized by the fact that it grows in six of the eight vegetation types studied. Grass seeds appeared to be preferred to rush and sedge seeds.

In spite of the fact that laurel oak trees are present in six of the eight vegetation types, they have a lower preference rating than live oak, which grows in considerable numbers only in two types, the oak-cabbage palm hammocks and the pine islands. The scarcity of live oak reproduction and saplings in the oak hammock is striking. In the future, after the old growth trees have matured and died, there will be a shortage of live oak trees to regenerate the stand. Laurel oaks and cabbage palms will fill in the canopy. This eventual replacement of live oak trees will probably force the turkeys to change their present fall and winter food habits over extensive areas.

Present studies now in progress by the School of Forestry, University of Florida, on the silviculture and management of cypress may bring to light new uses for small diameter cypress poles growing in cypress ponds and swamps throughout much of the present turkey range. The thinning and selective cutting of dense stands would be profitable and increase the growth rate. The additional sunlight and crown development would stimulate seed production thereby increasing an important turkey food source. Cypress trees along the edge of stands appear to bear heavier seed crops than their crowded neighbors in the interior of the stand.

A comparison of the total number of kinds of plants available per vegetation type to the number of plant foods eaten (Table 5) gives an idea of the relative value of each type.

TABLE 5.—COMPARISON OF THE TOTAL NUMBER OF KINDS OF PLANTS AVAILABLE TO THE NUMBER OF PLANT FOODS EATEN

Vegetation type	Average number of plants recorded from plot study*	Number of plant foods eaten by turkeys
Pine flatwood woodland	48	15
Pine islands	40	16
Oak-cabbage palm hammock	45	12
Cypress ponds and swamp	51	23
Wet prairie grassland	30	11
Dry prairie grassland	23	11
Mesophytic hammock forest	67	29
Swamp forest	81	30

* 210 quarter-acre plots.

It is apparent from the relatively large number of food plants available in the mesophytic hammock and swamp forests that turkeys can find a wider variety of food plants in these two types than in any one of the other types. Turkeys in areas where the other six types are well interspersed can range into several of them in a day's feeding to satisfy their needs.

It appears from this vegetation and food habits study that the main source of food supply for turkeys in central and southern Florida in the fall and winter occurs in the oak-cabbage palm hammocks and the pine islands. During the other two seasons of the year, the food supply is distributed widely in several vegetation types.

SUMMARY

1. Thirty-two turkey crops, representing the months of October, 1952, through Janu-

ary, 1953, were collected from ten different areas on the Florida peninsula.

2. Acorns made up 53.8 per cent by weight of all food eaten. Live oak acorns were the most important single food item consumed, constituting nearly half, or 48.5 per cent of the total food eaten, and 90 per cent of all acorns taken.

3. Other major vegetable food items, totaling an additional 38 per cent, in decreasing order of importance are: paspalum grass seed, slash pine seed, black gum seed, longleaf pine seed, yellow-eyed grass heads, and sweet-rush tubers. Plant material contributed 97.1 per cent of all food eaten. Each crop contained an average of eight different plant food items.

4. Major animal foods, totaling 2.9 per cent by weight, were dragonflies, grasshoppers, and moth larvae. More than three-quarters, or 81 per cent, of the crops contained some animal matter.

5. Grass leaves, amounting to 21 per cent in volume, were the major food eaten on a year-round basis as determined from 2,775 droppings collected from 16 areas.

6. Ten other important foods found in droppings in decreasing order of importance were: panic grass seed, acorn fragments, paspalum grass seed, corn, wax myrtle seed, gallberry seed, beetles, carpet grass seed, grasshoppers, and cabbage palm berries.

7. Plant items in the droppings composed 96.4 per cent of all food eaten by turkeys on an annual basis. Animal matter amounted to 3.6 per cent.

8. The prominence of grasses in the food of the wild turkey accentuates the importance to turkeys of the trend toward the establishment of improved pastures on vast areas of turkey range in Florida.

9. Control of feral hogs would tend to increase the supply of acorns in many areas.

10. Self feeders filled with corn appear to supplement the turkeys' food supply during the late winter and spring during periods of native food shortage. Feeders are not used extensively during the summer and fall when native food is abundant.

LITERATURE CITED

ANON. 1950. The Florida wild turkey. Florida Game and Fresh Water Fish Commission, Tallahassee. 45 pp.

BAILEY, R. W., H. G. UHLIG, and G. BREIDING. 1951. Wild turkey management in West Virginia. Conservation Commission of West Virginia, Charleston, 49 pp.

BAUMGARTNER, F. M., M. J. MORRIS, J. L. STEELE, and J. E. WILLIAMS. 1952. Oklahoma bobwhite food relations. Trans. N. Amer. Wildl. Conf., **17**: 338–359.

CULBERTSON, A. B. 1948. Annual variations in the early winter foods of wild turkey and their management implications. Unpub. thesis, Virginia Polytechnic Institute. Blacksburg, Virginia. 118 pp.

DALKE, P. D., W. K. CLARKE, JR. and L. J. KORSCHGEN. 1942. Food habit trends of the wild turkey in Missouri as determined by dropping analysis. Jour. Wildl. Mgt., **6**: 237–243.

DAVIS, J. H. 1943. The natural features of southern Florida, especially the vegetation and the Everglades. Fla. Dept. Cons. Geol. Survey. Bulletin No. 25. Tallahassee. 311 pp.

GOOD, H. G. and L. G. WEBB. 1940. Spring foods of the wild turkey in Alabama. Amer. Wildl., **29**(6): 288–290.

LAESSLE, A. M. 1942. Plant communities of the Welaka area. Univ. Fla. Pub., Biol. Sci. Ser., **1**(4). 143 pp.

MARTIN, A. C. 1949. Procedures in wildlife food studies. U. S. Fish and Wildlife Service, Wildl. Leaf. 325. 10 pp. (Mimeo.)

MAY, F. H., A. C. MARTIN, and T. E. CLARKE. 1939. Early winter food preferences of the wild turkey on the George Washington National Forest. Trans. N. Amer. Wildl. Conf., **4**: 570–578.

MOSBY, H. S. and C. O. HANDLEY. 1943. The wild turkey in Virginia: its status, life history, and management. Virginia Comm. of Game and Inland Fisheries, Richmond. 281 pp.

OOSTING, H. J. 1948. Plant communities. W. S. Freeman and Co., San Francisco. 389 pp.

WHEELER, R. J., JR. 1948. The wild turkey in Alabama. Ala. Dept. of Cons., Montgomery. 92 pp.

WILSON, K. A. 1945. Wild turkey and other upland game survey and a game management study in Western Maryland. Annual Report Maryland Game and Inland Fish Commission. pp. 25–41.

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AGE DETERMINATION IN YELLOWSTONE CUTTHROAT TROUT BY THE SCALE METHOD

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Age determination of various subspecies of cutthroat trout has posed a problem for fishery workers in the West for many years. Recognition of annuli has been somewhat more difficult than in trouts forming larger numbers of circuli, and obvious discrepancies have appeared when workers attempted to relate numbers of annuli to actual ages. This difficulty has resulted in a general tendency on the part of biologists to avoid reading cutthroat trout scales. No other method of aging this species has been explored extensively.

Biologists of the U. S. Fish and Wildlife Service faced the problem of aging Yellowstone cutthroat trout (*Salmo clarki lewisi*) when they began investigations on that species in Yellowstone Lake in 1950. The Yellowstone studies have been concerned with determining safe fishing pressure for Yellowstone Lake and the Yellowstone River. The investigation has had several facets, and progress has been reported (Moore, Cope, and Beckwith, 1952; Cope, 1953). The scale-collecting program proceeded according to schedule from year to year, but scale reading lagged because of difficulties in assigning ages to the different fish.

The present paper explains the methods developed for age determination in cutthroat trout from Yellowstone Lake and connecting waters. The biology of the fish in its first year has proven to be variable in its effect on the scale, and the principal problem in age determination lies in the interpretation placed on the structures in the center of the scale.

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Lake Yellowstone, at an elevation of 7,731 feet, has an area of 137 square miles, and an irregular shoreline 100 miles long. It extends 20 miles in a north-south direction and 14 miles from east to west (Fig. 1).

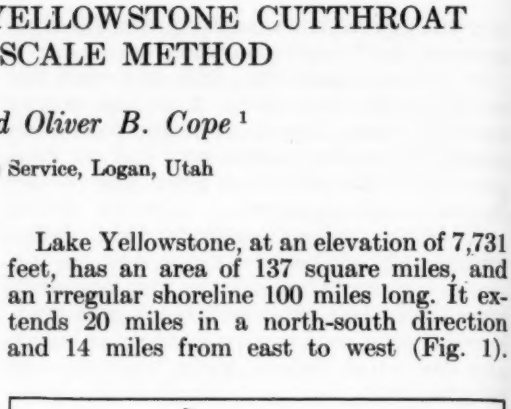

FIG. 1. Yellowstone Lake and lower Yellowstone River, showing streams from which cutthroat trout have been collected.

The Absaroka Range drains into the lake on the east, and the Upper Yellowstone and the Thorofare Creek drainages empty into the south end of the lake.

Ice covers the lake about six months of the year. Mean monthly air temperatures range from 10.7°F. in January to 59.3°F. in July. The mean annual temperature recorded at Lake Ranger Station is 32.5°F. Precipitation is a little heavier during the first six months than during the latter half of the year. Annual precipitation averages 20.16 inches.

Yellowstone Lake cutthroat trout have a

prolonged spawning period which begins in May and lasts until late July. Fry begin to emerge from the gravel late in June, and the hatch continues until early September. Since the growth rate declines to negligible values in October, (Brown and Bailey, 1952) late fry do not reach the size at which scale formation is initiated. Those reaching a length of 41 to 44 millimeters usually have distinguishable scale platelets. Scales appear first along the lateral line and develop progressively dorsad and ventrad as determined for this species by Brown and Bailey (*op. cit.*) and for other species by various authors. Since the center of most rapid growth shifts caudad during an early stage of development, the peduncle is fully scaled earlier than the medial parts of the body. In order to make age determination as accurate as possible for fish whose early growth is so variable, it is necessary to devise a method for identifying scales which did not form an annulus after the first season of growth.

Definite criteria have been established for identification of "normal" as contrasted with "retarded" scales. Normal scales are defined as those with growth checks at the end of the first growing season, and retarded scales are those that fail to form a check at that time.

A limited amount of work has been done on the biology of the Yellowstone cutthroat trout at Yellowstone in other places. Robertson (1947) investigated the cutthroat trout population of two high-mountain lakes in the Wind River Range, Wyoming. Fleener (1951) studied the life history of cutthroat trout in Logan River, Utah, where they occurred mostly in Age-groups I and II in the headwaters. Brown and Bailey (*op. cit.*) determined the time and pattern of scale formation for a sample of 200 immature cutthroat trout in a tributary of Yellowstone Lake in 1949. Irving (1953) explored the ecology of the species in Henrys Lake, Idaho, a few miles west of Yellowstone Park. Two studies on the Lahontan cutthroat trout, *Salmo clarki henshawi* have been conducted in California, where Smith (1941) investigated natural spawning success at Convict Creek, and Calhoun (1944) reported on spawning and reproduction at Upper Blue Lake. Willoughby (1951) analyzed the age and growth of cutthroat trout obtained from the 1949 spawning runs at Pelican and Chipmunk Creeks, tributaries to Yellowstone Lake.

COLLECTION, PREPARATION, AND EXAMINATION OF SCALES

Scales for study were obtained from trout taken in the fishery, from spawners entering tributary traps, and from immature fish captured in streams and along the lakeshore. Sampling of the fishery was begun with the opening of the fishing season on May 30, from 1950–1952. In 1953, the opening date was postponed until June 15 thereby delaying the collection of data.

The operation of traps in several streams during early May made it possible to intercept early spawners. These early collections, principally from Pelican, Arnica, Clear, Grouse, and Chipmunk Creeks (Fig. 1) are especially valuable for studies on time of resumption of growth. Scales were collected routinely from these streams, as well as from Cub Creek, during several entire seasons. The data from Arnica Creek were extensive for both upstream- and downstream-migrating adults. A program of fin clipping and scale collecting from lakeward-migrating immature fish in Arnica Creek produced valuable information pertaining to early life history. This marking program also provided adult fish of known age from the returns of marked fingerlings to their parent streams. Scales from 56 of these known-age fish were used for reference in age determinations. Only spawners were taken in the stream traps. Non-spawners and sexually immature fish were not available until later in the year, since they come principally from anglers' creels.

Other cutthroat trout for scale samples came from a Lake Erie type trap-net fished in Yellowstone Lake just southeast of the Yellowstone River outlet. Trap-net collections included smaller, younger fish than the spawning runs. Several hundred upstream migrants were tagged annually at the Yellowstone River Cascades (5 miles below the lake outlet), dip nets being used to capture the fish as they congregated in pools. Recoveries of marked fish from the extensive tagging program on the lake have yielded information on the biology of the cutthroat trout.

Scale collections from the lake and river fisheries were made periodically throughout the season. In 1953, immature trout were

captured from the lakeshore, river, and tributary streams for information on scale development in their first and second years of life. Some immature fish were taken October 23, 1953, for data on the late-season development of these fish.

Scales from adult fish were taken from the area between the dorsal fin and the lateral line. Scales from immature trout were obtained both from the area between the dorsal fin and the lateral line and also from the caudal peduncle for the purpose of measuring the differences in scale development in the two areas. After cleaning, four typical scales were mounted on glass slides in glycerin-gelatin or gum arabic medium.

A Bausch and Lomb Euscope was used for viewing scales. The apparatus consisted of a 60-power compound microscope equipped with a prism above the ocular. A light-tight box 12 inches long, fitted with a 6-inch screen was mounted above the microscope. The proximal end of the box was fashioned to fit the face and was equipped with a rectangular lens for magnifying the scale image. The equipment provided good definition without discomfort to the reader even with continuous use. All scales were read twice; the more questionable ones were discarded. Aging was verified by periodic checking by another scale reader. Photographs of scales were made with a microprojector.

NORMAL AND RETARDED ANNULUS FORMATION

The streams entering Yellowstone Lake vary in quantity and quality of spawning gravel, in gradient, in water volume, in fluctuations of flows, in temperature, in abundance of food organisms, and in chemical characteristics. Temperatures and chemical characteristics appear to exert the greatest influence on growth and scale development. In some areas geysers and hotsprings empty their hot, chemically-charged effluents into streams. For example, fish are prevented from entering sections of Pelican and Clear Creeks in the vicinity of geyser basins through which they flow. It is presumed that failure of immature fish to migrate at normal times retards growth and scale development. These unfavorable stream conditions are exaggerated during periods of high isolation and reduced precipitation.

The survival of a particular spawning, during and after the period of incubation, is conditioned by the stream and climatic conditions. The variability in size of fingerlings in the fall of any brood year reflects the extent to which environmental conditions were favorable during the summer. For example, if fish with retarded scales constitute an abnormally large percentage of the year class, it is presumably the result of greater survival of the progeny of late spawning. Observations made during 1954 stream surveys indicated that, in September, young of the year were of greater average size in Pelican than in Cub Creek. This difference can be attributed to the later spawning run and lower stream temperature in Cub Creek.

Brown and Bailey (1952) divided first-year fish into the following groups on the basis of scale development:

1. Fish completely scaled before the first winter and having the first year mark on their scales.
2. Fish partially scaled before the first winter, having some scales with, and some scales without, the first year mark.
3. Fish which have no scales before the first winter, and hence form the first annulus only after the second growing season.

As used in the present paper, partially scaled fish were defined as those exhibiting three or less circuli at the end of the first growing season. Fish in this group appeared to form annuli only after the second growing season. The 1953 collections of scales from immature fish were examined with a view toward determining the frequencies of occurrence of the developmental groups listed above. The results of the examination of 272 fish assumed to belong to Age-group I are shown in Table 1. The group classed as completely or almost completely scaled by the end of the first growing season were identified by the presence of four to six circuli. This criterion was established by repeated observations on immature and adult trout, which indicated that almost without exception there was a minimum of four circuli within the first recognized annulus. The partially scaled group was most plentiful in the 1953 example (35.8 per cent of the scales examined), the unscaled group had the second greatest occurrence (32.7 per cent), and the fully scaled group averaged 31.5 per cent of the sample (Table 1). The collections may not have been representa-

TABLE 1.—SCALE DEVELOPMENT AND LENGTHS OF AGE GROUP I FISH COLLECTED IN 1953

Locality	Date of Capture	Unscaled				Partially Scaled (1–3 Circuli)			Fully Scaled (4–6 Circuli)		
		Number	Percentage	Mean length*	Range in length	Number	Percentage	Mean length	Number	Percentage	Mean length
Arnica Creek	May 5, 1953	5	23.8	43.0	40–46	9	42.9	50.5	7	33.3	51.3
Little Arnica Creek	May 5, 1953	13	76.5	37.5	31–46	3	17.7	51.3	1	5.9	60.0
Below Fishing Bridge	May 11, 1953	4	6.8	41.5	40–43	30	50.9	47.5	25	42.3	54.7
Hatchery Creek	May 11, 1953	4	30.8	40.8	36–44	7	53.9	45.9	2	15.3	48.0
Little Thumb Creek	May 13, 1953	40	62.5	41.6	35–48	19	29.7	51.8	5	7.8	56.2
Bridge Bay	May 17, 1953	1	6.3	44.0	.....	2	12.5	50.5	13	81.2	57.7
Fishing Bridge Dock	Oct. 23, 1953	18	22.0	39.9	35–44	35	42.7	48.0	29	35.3	55.9
MEAN VALUES			32.7	41.2			35.8	49.4		31.5	54.8

* Average total length in millimeters.

tive of the entire stock since only seven localities were sampled.

Most of the fingerlings were taken in May, but a sample of 82 was obtained on October 23. This fall collection was judged to be composed entirely of young of the year on the basis of size distribution and scale appearance. Squamation was evident on 78 per cent of the collection which ranged from 35 to 65 millimeters in total length. The appearance of their scales was characterized by extreme transparency and by the uniform lack of contrast exhibited by circuli. Further calcification presumably occurs during the winter, since the scales of Group I fish of the same average size taken in the previous May, were more refractive. The number of circuli varied from 0 to 6, the smallest fish with discernible dorsal scales being 41 millimeters in length. Four out of ten specimens in the 41 to 43 millimeter range yielded scales. Most of the fingerlings measuring 45 to 50 millimeters had 1 to 3 equally spaced circuli. Larger ones generally had scales with 4 to 6 circuli of which the marginal ones were crowded together in the anterior field to form the year mark. Initial circuli enclosed areas up to 0.5 inch in longest diameter irrespective of scale size (magnification 110×).

The scales of 59 fingerlings taken in an adjacent area May 11, 1953, were found to be comparable in size and numbers of circuli to the October collection. In both of the groups there were from 0 to 6 circuli. The size range of the fish in the May collection from Fishing Bridge was 40 to 65 millimeters—very similar to the size distribution of the fall sample except for the presence of a greater number of unscaled fingerlings in the latter group. Scale development appeared to be comparable for equal-sized fish in both collections. The scales of the specimens were measured and circuli enumerated. The data were combined and mean scale length was plotted against total length by 20 millimeter intervals in order to show the body-scale relationship of fish at the end of the first growing season (Fig. 2). Since the evidence indicated that

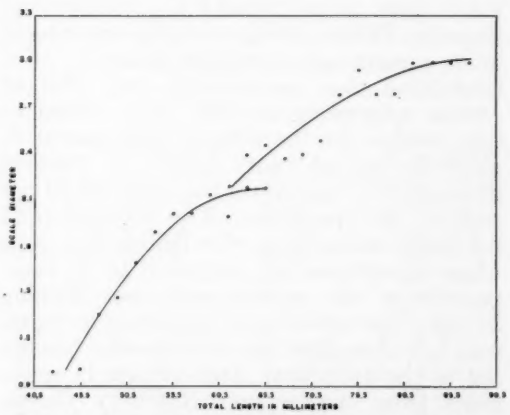

FIG. 2. Body-scale relationship of immature Yellowstone cutthroat trout. Date for lower curve obtained from 119 trout presumed to be Group O and Group I. Upper curve based on data from 32 fingerlings presumed to be Group II.

the Fishing Bridge area samples were homogeneous as to age composition, the body-scale relation was based on these fish only, in order to avoid the necessity of selecting young of the year on arbitrarily established bases.

The diameter of the scale along the long axis was measured and the average length of the three largest scales was recorded to the nearest tenth of an inch under a magnification of 110×. A second-degree curve was fitted to the data by Fisher's summation method of fitting orthogonal polynomials (Goulden, 1952) by means of the equation: Scale length = $1.75+.05734\xi_1-.0038145\xi_2$.

The data indicate that the body-scale ratio was nearly linear in the range between 47 and 55 millimeters. Earlier scale growth was slow, and a progressive lag in scale growth is evident in fish above 55 millimeters in length. The fitted curve corresponds generally to curves for adult populations. The second curve plotted in Figure 2 permits a comparison of the Age-groups 0 and I with fish considered to be Group II. The data for the upper curve represents measurements on 32 fingerlings which were believed to belong to the 1951 year class on the basis of more numerous circuli (8 or more, a few had 7 circuli). The fish measured from 62 to 92 millimeters in total length. Initial circuli on about 10 per cent of the sample had a characteristically "open" appearance measuring 0.6 to 0.7 inch in diameter on the long axis. As previously indicated, none of the Group 0 and I fingerlings from the Fishing Bridge vicinity had central areas exceeding 0.5 inch in diameter. It is postulated that scales with the enlarged central area occur on fish which failed to form scales (in the area of skin sampled) until its second year. Annuli of varying distinctness occurred on the scales of 20 per cent of the specimens. The Age-group II fish were seined from the Bridge Bay area where conditions are presumed to be comparable to the environment near Fishing Bridge. The collection is presumed to represent fish of smaller than average size belonging to the 1951 year class. Group II specimens from Arnica and Hatchery Creeks were excluded, since scales from fish in these collections were typically "stream type" with relatively small size and with crowded circuli. The data for body-scale lengths of Group II fingerlings was fitted with a curve by Fisher's summation method (Goulden, *op. cit.*) having the following equation: Scale length = $2.69 + 0.3301\xi_1 - 0.0592\xi_2$.

The points about the upper curve in Figure 2, representing mean scale length for each interval of total length, display considerable scatter attributable to any of three causes. The possible heterogeneity of the population sampled, possible lack of randomness due to small sample size, and the necessity of using the average of the largest, instead of key scales, may have contributed to the dispersion.

In general, it appears that the relationship of scale and body length tends to be linear in the median range and progresses toward an asymptote near the upper size limit in both age groups. While there is a region of overlap in the body as well as the scale length in the two groups of fish on which the curves are based, the difference in slopes suggests that they probably are different age groups. Measurements and circulus counts on normal and retarded scales of adult fish were also compared (Table 3). Significant differences were found to exist between the two types of scales.

As a result of the prolonged spawning season, fry were in various stages of scale formation at the end of the growing season. Brown and Bailey (1952) found that fingerlings 54 to 61 millimeters long had formed less than half their scale rows above the lateral line during the first summer. The median length of the fingerlings collected in 1953 was about 50 millimeters. These facts suggest that in their first summer a large percentage of all fingerlings can be expected to lay down none or only part of their ultimate scale rows in the area normally sampled for scales. A study of the 1953 fingerlings showed that although some degree of squamation occurred in two-thirds of the fish examined, first-year annuli occurred on only 31.5 per cent of the population (Table 1), since late-hatched fry which form rudimentary scales nevertheless fail to establish a year mark until after the second summer.

The annulus, as it appears in cutthroat trout scales, conforms in a general way to the usually accepted definition. However, the small scale size and the presence of small numbers of circuli in the average year's scale growth, complicates the aging technique. Van Oosten (1929) described the annulus of the lake herring as a band of

faint, much broken, anastomosed, and more closely approximated circuli formed during a period of retarded growth. The year-mark on the scale of the cutthroat trout is scarcely a band, or at best is a very narrow one since it usually involves only 2 or 3 circuli. Growth cessation appears to be abrupt, and the broken, anastomosed circuli constituting the year mark occur in the anterior and lateral fields. Occasionally a single faint and irregular circulus indicates the occurrence of the annual growth check. Age group I fish having only 2 or 3 circuli in May, usually have circuli that are equally spaced and of uniform appearance. Although these first-year circuli often appear to be capable of differentiation from later ones on the basis of optical differences, circulus counts seem to be the more reliable single basis for the recognition of retarded annulus formation.

Occasionally, a false annulus is recognizable by the incompleteness of the growth check in the lateral fields and by its occurrence in the area representing summer growth. Since Yellowstone Lake temperatures probably never reach unfavorably high levels, the false checks are probably effects of late spawning, disease, or injury. Temperatures in some streams may reach unfavorable levels for short periods, as at Arnica Creek where afternoon readings were above 70°F. during the latter portion of the 1953 spawning run. This condition may produce false checks on scales. A few fish taken and returned to the water by anglers may suffer injury sufficient to produce a growth check. Irving (1953) reported well-defined false checks on cutthroat trout in Henrys Lake where high temperatures and reduced oxygen tensions coincided with a cessation of feeding during the late summer.

Investigation of the time of annulus formation in the fall is made difficult by waning fishing effort and success. In 1953, the season's last adequate sample at West Thumb was collected on August 25, at which time scales showed no evidence of slowed growth.

TIME OF ANNULUS FORMATION

Annuli were assumed to have been completed when a continuous new circulus appeared outside the seasonal growth check. Adult fish taken in traps and in the early fishery were examined to determine the presence or absence of current scale growth (Table 2).

Approximately one-half of the fish taken during the first 3 days of the run in Arnica Creek, where the first 1953 migrants entered the trap on May 5, had newly formed circuli on the scale margin, and were therefore considered to have recently formed an annulus.

To determine whether time of resumption of scale growth was conditioned by calendar age, the fish were divided into size groups. Of all specimens examined, annulus formation had occurred in 87 per cent of those up to 13 inches inclusive compared to 50 per

TABLE 2.—PERCENTAGE OF ANNULUS FORMATION, BY AGE-GROUPS, IN YELLOWSTONE LAKE

Locality	Date	Number of fish sampled	Percentage of scales with annuli		
			Age groups		
			III & IV	V	VI & above
Arnica Creek Trap	May 5–14, 1953	55	81 (26)[1]	41 (17)	25 (12)
" " "	May 18–20, 1953	29	93 (15)	71 (7)	43 (7)
" " "	June 1, 1952	34	85 (20)	41 (11)	100 (3)
" " "	June 10–13, 1953	49	100 (7)	85 (27)	53 (15)
" " "	June 16, 1952	16	100 (10)	75 (4)	100 (2)
Pelican Creek Trap	May 20, 1952	47	85 (13)	12 (25)	0 (9)
" " "	June 10–12, 1953	31	100 (6)	100 (10)	60 (15)
Fishing Bridge Dock	June 6–9, 1950	62	80 (20)	32 (28)	14 (14)
" " "	June 16, 1951	23	67 (3)	50 (10)	30 (10)
" " "	June 16, 1953	22	100 (9)	22 (9)	0 (4)
West Thumb Dock	June 10, 1952	23	83 (19)	0 (4)	....
" " "	June 16, 1952	17	100 (16)	100 (1)	....
" " "	June 16, 1953	20	100 (17)	50 (2)	0 (1)

[1] Numbers in parentheses represent numbers of fish.

cent in the group larger than 13 inches. When divided into groups above and below 15 inches total length, current scale growth was evident in 72 per cent of the smaller and 28 per cent of the larger specimens. Hence, seasonal growth resumption was delayed in fish of larger size.

The effect of age on annulus formation is shown in Table 2 which reveals that in the June 16 collection of all years, almost every Group III fish had completed annulus formation. A comparison of spawning migrants with specimens from the fishery (Fig. 3)

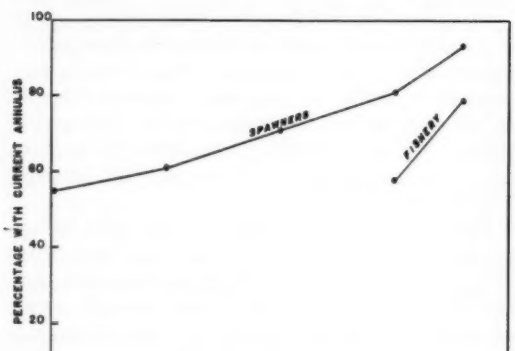

FIG. 3. Percentage of annulus formation in 428 fish of Age-groups III, IV and V in the fishery and spawning runs of 1951–53.

shows higher percentages of annulus formation in the spawners. The graph suggests that early-season spawners resume scale growth in the spring before late or non-spawning trout do. Almost all 3- and 4-year-old fish completed annulus formation by June 15.

Collections of scales made during the first half of June from 1950 through 1953 were examined for extent of annulus formation by areas. A sample of 160 fish landed at West Thumb and Fishing Bridge docks showed annulus formation in 80 and 50 per cent of the fish, respectively. However, the Fishing Bridge specimens were longer on the average (383 millimeters) than fish of the West Thumb collections (335 millimeters). About 80 per cent of the smaller fish (below 14 inches) in both groups had formed annuli. Brown and Holton (1953) found that annulus formation was completed in young rainbow trout by June 3, and in brook trout by June 25 in Trout Creek, a spring-fed stream located in the Gallatin Valley, Montana.

CUTTHROAT TROUT SCALES

The difficulties encountered in attempting to read the scales of Yellowstone cutthroat trout led to an evaluation of the unique morphological features of these scales. Special attention was given the structure of the focus, the spacing and numbers of circuli, the appearance of the scale surface, and the structure of the annulus. From this examination were developed standards for determining the age of Yellowstone cutthroat trout.

The part of the scale within the first annulus, and the part outside to a lesser extent, exhibit great variability with respect to several features. The size of the first annulus varies according to the amount of growth in the first year and according to the numbers of circuli within. This point will be discussed later but Yellowstone cutthroat trout scales appear to have from 4 to 16 circuli within the first year mark. The smallest number of circuli within a distinct annulus was four. The spacing of the circuli within the first annulus is remarkably uniform, considering the migratory nature of the fish. Very few scales with a so-called "stream nucleus" are found despite the fact that large numbers of the immature fish overwinter in streams. The examination of more than 1,300 scale samples from the Fishing Bridge and West Thumb areas for narrowly spaced circuli of the familiar "stream nucleus" disclosed only nine examples (0.7 per cent). This type of scale marking was more common in the West Thumb samples, where it occurred in two per cent of the fish examined. The size of the initial circulus is variable from fish to fish, depending upon the time of scale formation. Ordinarily, the central area has a radius very little greater than the distances between circuli in the area representing the first year's growth. Large foci occur in two situations: in the regenerated scale, and where no circuli are formed during the first season. The latter is important for recognition of retarded annulus formation, and will be discussed later. The shape of most foci, with the exception of regenerated ones, is characteristically oval, with smooth, regular contours. Regenerated scales of cutthroat trout have nuclei similar to those of other salmonids, *i.e.*, with irregular shape,

large size, and rough outlines on the first circulus. The surface bounded by the first circulus is sometimes seen as a coarse granular area. This condition is usually observed also on fish which fail to form annuli during their first winter.

The number of circuli formed during a year of growth in Yellowstone cutthroat trout scales is not as large as in certain other trout species. A small sample of Age-group II rainbow and cutthroat trout from Koosharem Reservoir, Sevier County, Utah, collected July 26, 1953, were compared as to numbers of circuli formed in the year preceding capture and in the current season. During the summer of 1952, the rainbow and cutthroat trout laid down an average of 19.5 ($\sigma \pm 0.7$) and 9.0 ($\sigma \pm 1.4$) circuli, respectively. By July 26th in 1953 they averaged 12.0 ($\sigma \pm 1.4$) and 6.5 ($\sigma \pm 2.12$) circuli for rainbow and cutthroat trout, respectively. It appeared that in the sample examined, rainbow trout laid down approximately twice as many circuli as cutthroat trout in the same period. Cutthroat trout from other waters have been examined for general comparison with rainbow and brook trout. Scales from small samples of rainbow trout collected from Fish Lake, Utah (elevation 8,600 feet) in 1933, resembled Yellowstone cutthroat trout in that first-year annuli occurred in one-half of the fish examined. (It was assumed that criteria for identifying first-year annuli in cutthroat trout applied to rainbow also.) Brook trout from the same waters showed more uniform first-year growth than did cutthroat and rainbow trout, and averaged 7 and 8 circuli in their first and second years, respectively.

The scales of cutthroat trout collected in 1933 from Scofield and Strawberry Reservoirs in Utah (elevations 7,625 and 5,725 feet, respectively) were examined for differences in scale characteristics. The scale samples from Strawberry Reservoir indicated that annulus formation occurred during the first year in almost every fish. Only about one-fifth of the fish from the higher and more oligotrophic Scofield Reservoir exhibited the first year mark.

In order to obtain a basis for distinguishing the normal and retarded scale types, the scales from Group I and II fingerlings taken in 1950–1953 were studied to determine limits of first- and second-year scale development.

Three scale characters were of value in helping to recognize retarded development:

1. Number of circuli inside the first annulus.
2. Size of the first circulus.
3. Shape and density of the first one or two circuli.

On the basis of information gathered in a study of scales from immature fish, (Table 1, Fig. 2) first annuli preceded by eight or more circuli were designated as second-year marks. Growth checks preceded by six or fewer circuli were considered to indicate termination of first-year growth. Studies by other workers have shown that annual growth increments were smaller at higher elevations. Robertson (1947), working with cutthroat trout of two high-mountain Lakes (10,500 ft.) in Colorado, and Curtis (1935), in a study of golden trout of the Cottonwood Lakes, California (11,000 ft.) both postulated that annuli preceded by five circuli or less were indicative of first-year scale growth. These workers found that scale development which had been delayed until after the first winter was indicated by seven or more circuli within the first growth check.

Scales which had only one or two incomplete circuli at the end of the first growing season were often recognizable in adult trout. Brown and Bailey (1952) pointed out that the first circuli are often incomplete anteriorly. The dark appearance of the first, second, and sometimes the third circulus is characteristic of some cutthroat trout scales and may be the result of growth interruption at one of these stages. Fingerlings which lack expected year marks, but which were presumed to be Age-group II on the basis of size and circulus counts, showed both of these characteristics. Scales from immature specimens collected late in October were examined to determine the extent of current annulus development. Fish mostly less than 50 millimeters in length having scales with not more than three circuli did not exhibit approximation of marginal circuli as evidence of annulus formation. Larger specimens displayed growth retardation at the scale margin as indicated by the crowded condition of the marginal circuli.

Representative scales illustrating types commonly encountered in age analysis were photographed at a magnification of 60× (Figs. 4 to 7). The magnification of figures 8, 9, and 10 was 50×.

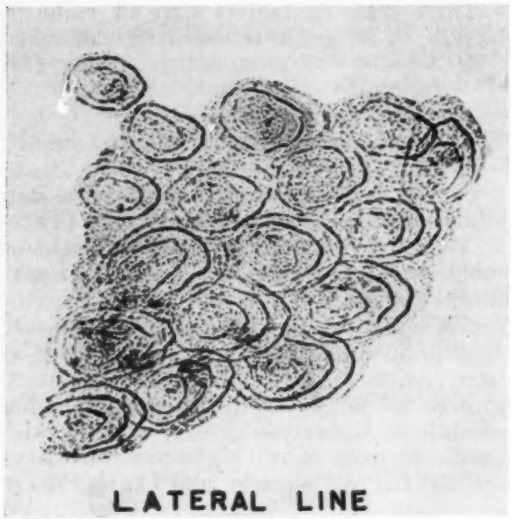

FIG. 4. Group of scales from an Age-group I fingerling showing developmental gradient with circuli increasing from two to four. 50 mm., near Fishing Bridge, May 11, 1953.

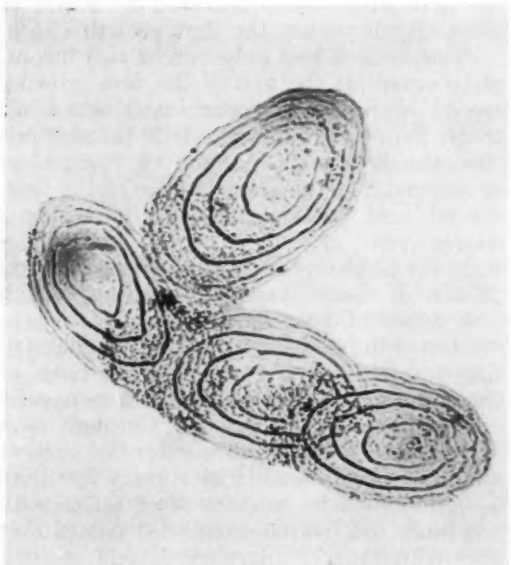

FIG. 5. Beginning of annulus formation in young of the year. 54 mm., at Fishing Bridge Dock, Oct. 23, 1953.

Figures 4 and 5 illustrate moderate scale development in fingerlings less than a year old. In the first photograph, a cluster of scales shows a developmental series with the more advanced scales oriented in the plane of the lateral line. Possible indications of marginal growth retardation by closer spacing of outer ridges occurred only in scales having four circuli. Figure 5 demonstrates slowed fall growth in a more advanced fingerling taken at the end of the first growing season. The scales in Figure 6 were ob-

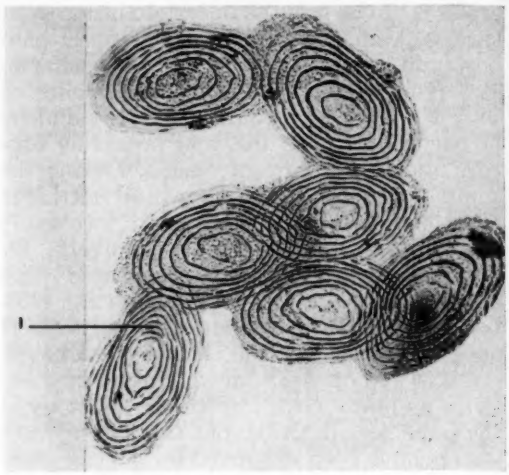

FIG. 6. Age-group II fingerling scales showing one normal and six retarded scales. 85 mm., Hatchery Creek, May 11, 1953.

tained from fingerlings judged to be in their second season on the basis of length and scale characteristics. A poorly defined first-year mark occurs on one scale but the six others generally conform to the retarded type. The larger number of circuli in the scale having an annulus indicates that it was formed earlier, probably during the first summer, while the larger foci and the absence of checks on the others suggest that they were initiated the following year during the period of rapid growth.

Figure 7 represents a scale obtained from a small fish taken in the lake trap net. Annuli were formed at the end of the first, second, and third growing periods. A large scale increment was established during May and June of 1953. While the third annulus is incomplete on the left field, other scales from the same fish exhibit more typical third annuli.

In Figure 8 the compressed circuli in the central area of the scale are typical of those found in immature stream residents. The enlarged focus and the number of circuli within the first annulus indicate that it is a

FIG. 7. Normal scale from Age-group III fish with three annuli. 280 mm., June 24, 1953, Lake trapnet.

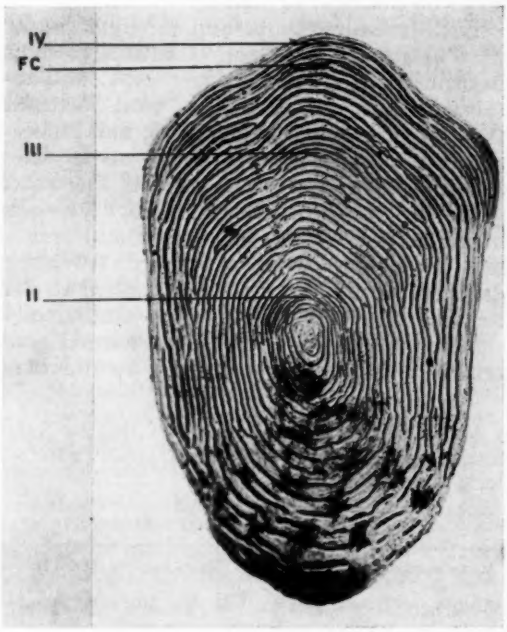

FIG. 8. Retarded scale from Age-group IV fish probably resident in a stream for two years. 305 mm., male, West Thumb, Aug. 4, 1953.

retarded scale. Movement into the lake apparently took place shortly after the resumption of spring growth in the third year. Rapid growth occurred during the following two years with a false check preceding the last annulus. Growth appears to have been slower during 1953, since only a small increment of scale growth is visible outside the last annulus.

Figure 9 represents a scale from a fish

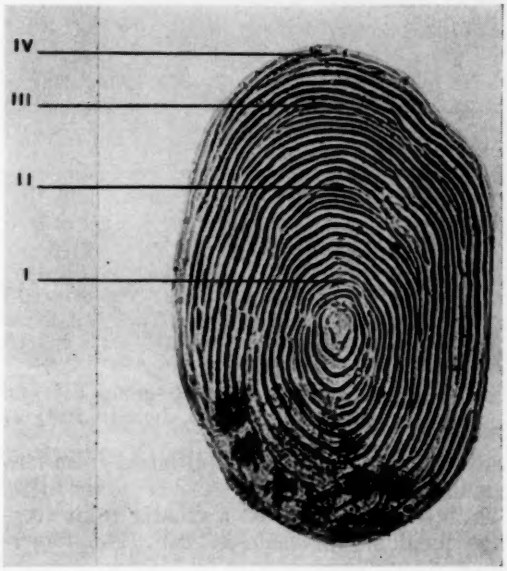

FIG. 9. Normal scale from Age-group IV fish. 310 mm., male, West Thumb, June 22, 1952.

having moderate and uniform development. The annulus was completed shortly before capture. Near-maximum longevity is represented by the scale in Figure 10. No fish older than 7 years have been encountered in routine scale examination.

FREQUENCY OF NORMAL AND RETARDED SCALES

Both adult and immature fish were studied to determine the frequency of normal and retarded initial annuli. Since first-year marks are rarely preceded by less than four circuli in Yellowstone Lake cutthroat trout, it is assumed that immature fish having three circuli or less during the first summer will usually not form annuli until they have completed their second summer. Approximately 31.5 per cent of the 1953 collection of fingerlings had scales with 4 or more circuli (Table 1) and these usually exhibited marginal growth retardation. However, about 67.3 per cent of all the fingerlings of Age-group I had at least some indication of scale

FIG. 10. Retarded scale from Age-group VII fish. 405 mm., male, West Thumb, June 15, 1950.

development. Specimens obtained from two small streams (Little Arnica and Little Thumb creeks) showed a greater than average incidence of scaleless fish. The fingerlings which were present in May were probably dominated by late-hatched individuals. A higher incidence of squamation occurred in collections from stream mouths and the lakeshore. Extent of scale development was positively correlated with the average size of specimens in the samples. The two spring-caught groups having the shortest average length had the smallest percentage of fingerlings with scale development to the four-circulus stage. Scales usually appeared first in fingerlings 41 to 44 millimeters in length. About one-third of the fingerlings collected demonstrated fall retardation of growth at the margin which is generally apparent in individuals only after they reach the four-circulus stage. It is of interest that about the same proportion of fingerlings and adult fish in the combined samples examined exhibited normal first annuli, *i.e.*, growth checks established during the first year of life.

Scales from 420 adult fish from West Thumb Dock and Fishing Bridge Dock were examined for first-year annuli. (The previously mentioned criterion of eight or more circuli within the first growth check was assumed to indicate failure to form the first year mark). About 40 per cent (unweighted mean) of both the West Thumb and Fishing Bridge samples displayed normal scales. The range of variation was from 30 to 60 per cent (Table 3).

Scale measurements and circulus counts were also made to permit quantitative comparisons of these values in normal and retarded scales. The circulus count included the ridges from the focus up to, and including, those in the first year mark. The anterior radius measurement was the mean value to the closest millimeter under a magnification of 110. The mean and standard deviations were calculated for each group of data. A '*t*' test was applied to determine the probability of a statistically significant difference between normal and retarded scales with reference to numbers

TABLE 3.—A COMPARISON OF NORMAL AND RETARDED SCALES WITH REFERENCE TO LENGTHS OF RADII AND NUMBERS OF CIRCULI WITHIN THE FIRST ANNULUS. SCALE SAMPLES WERE OBTAINED FROM CREEL SAMPLES ON WEST THUMB DOCK AND FISHING BRIDGE DOCK

Area	Date	Number of scales	Percentage normal	Normal		Retarded	
				Mean number of circuli	Mean length[2] of radius	Mean number of circuli	Mean length of radius
West Thumb Dock	June 18–25, 1951	50	42	4.7 (0.71)[1]	17.7 (4.24)	8.3 (1.14)	29.7 (4.57)
Fishing Bridge Dock	June 17, 1951	38	30	4.6 (0.68)	16.4 (2.02)	9.0 (1.73)	29.6 (8.24)
West Thumb Dock	June 10–22, 1952	99	41	4.5 (0.88)	16.2 (5.51)	9.3 (1.94)	31.1 (6.27)
Fishing Bridge Dock	June 12–23, 1952	96	56	4.9 (0.78)	16.6 (4.08)	8.7 (1.54)	29.2 (6.06)
West Thumb Dock	June 16–July 14, 1953	59	35	4.3 (0.48)	14.7 (3.39)	8.9 (1.45)	27.5 (5.46)
Fishing Bridge Dock	June 16–July 6, 1953	78	33	5.0 (0.82)	17.1 (2.85)	8.4 (0.82)	28.0 (4.90)

[1] Values in parentheses represent standard deviations.
[2] Lengths represent anterior scale radii measured in millimeters to the outside of the first distinct annulus and magnified by 110.

of circuli and anterior radius measurements, respectively. In each case the differences were significant at the 99 per cent level.

In the course of the above scale examination, 10 scale mounts were observed to have both normal and retarded scales from the same fish. Evidently, annuli were established on a part of the scales on these fish (Fig. 6). Other scales on each of the specimens failed to form a year mark. Circulus counts and anterior radius measurements were made for both normal and retarded types. As it would be expected, the normal scales had smaller anterior radii (13.9 millimeters) with fewer circuli (4.1) than the average for normal scales in Table 3. Furthermore, the retarded scales had a greater average scale radius (31.6 millimeters) and more numerous circuli (9.4) than the average in retarded fish. This greater than average development of the retarded scales was to be expected since the presence of some normal scales on each specimen at the end of their first growing season suggests that the group were intermediate between the arbitrarily designated "partially" and "fully" scaled groups.

A further measurement was made to permit a comparison of anterior radius length at the end of two year's growth in normal and retarded fish, respectively. The average normal scale radius at second annulus was 34.2 millimeters—about eight per cent greater than in scales exhibiting retarded annulus development. The small difference in mean absolute scale size at the end of two years' growth would not necessarily bear on the relative usefulness of normal, as compared with retarded scales, in the back calculation of lengths at such annuli as are present on Yellowstone cutthroat trout scales.

The percentage of normally scaled fish appeared to be correlated with various factors in the life history. The influences of reproductive activities, seasons, age, and size, on occurrence of fish with normal scales were tested in an attempt to determine what possible quantitative relationships should be further investigated. Figure 11, which indicates the percentages of normal scales by 10-millimeter length intervals, shows that scales from more than 60 per cent of fish between 275 and 315 millimeters in length have normal first-year annuli. Fish 325 to 405 millimeters long were almost equally divided between normal and retarded types.

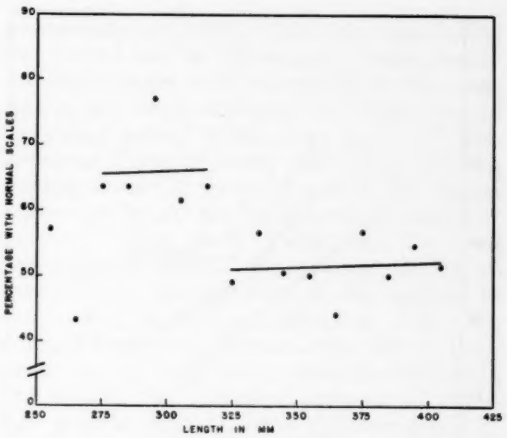

FIG. 11. Percentages of fish with normal scales plotted against total length. The sample includes 900 fish from the spawning and fishery runs during the 1950–53 seasons.

The data on either side of the 320-millimeter mark were fitted with separate trend lines to show general tendencies.

The points corresponding to lengths of 255 and 265 millimeters were omitted from the calculated line. The 265 millimeter length group represents a number of small Group III fish having a high percentage of retarded scales.

It is postulated that the greater proportion of fish with normal scales in the fish having average total lengths of 275 to 315 millimeters reflects differential recruitment. This hypothesis will be discussed later. A calculation of mean lengths of normal fish of Age-group III showed them to be about 10 millimeters longer than the comparable group exhibiting retarded annulus formation. Their larger size accompanied by possible developmental superiority appears to result in greater vulnerability of the normal trout. Normal fish predominate over retarded ones in the Age-group III spawners also (Fig. 12). The curves in Figure 12 show the frequency of occurrence of the two scale types in the early fishery (June) and the late fishery (August), each of the curves representing about 300 specimens collected in 1952 and 1953. West Thumb and Fishing Bridge areas are equally represented in the two curves.

The appearance of larger numbers of Group II fish in the late fishery distinguishes it from the early collection, in which only

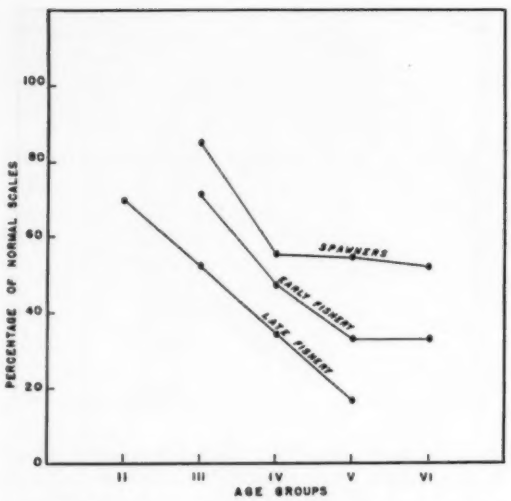

FIG. 12. Percentages of normal scales in various age groups of three seasonal samples from 1952 and 1953.

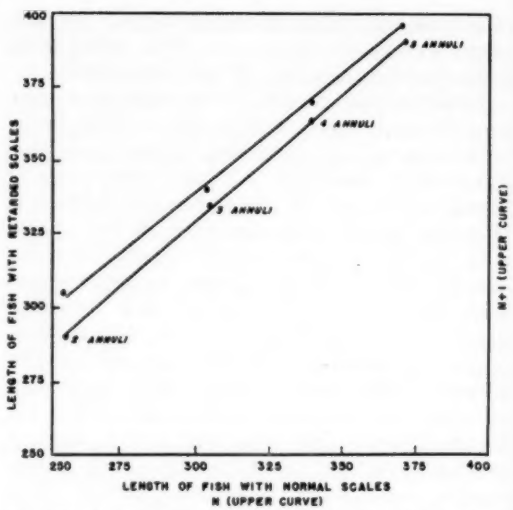

FIG. 13. Lower curve compares lengths of fish having normal scales with those having retarded scales. Points on curve represent lengths, in mm., at equal numbers of annuli. Upper curve shows lengths of normal fish at age n plotted against length at $n+1$.

two of these showed up. Predominance of fish with first-year annuli in the group of youngest fish supports the hypothesis that unequal recruitment obtains in the population segment comprising Group II and Group III trout. The low percentage of fish with normal scales in the sample of Group V individuals from the fishery, is consistent with year-class data to be presented later.

In order to obtain additional comparative data on normal and retarded fish, their growth rates were compared according to the method described by Walford (1946). The present application is a modification of the original method since the values plotted against each other differ by something less than a yearly increment (Fig. 13). Walford's method consisted of representing the growth curve (or the portion of it above the inflection) as a straight line. The mechanics of plotting the data are quoted as follows:

"Using arithmetic graph paper, with body length represented along both the x axis and along the y axis, plot length at ages 1, 2, 3, 4, 5, ... n on the x axis against length at ages 2, 3, 4, 5, 6, ... $n+1$ respectively on the y axis. . . . This line can be regarded as a sort of transformation of the usual growth curve. . . ."

The lower curve was obtained by plotting against each other the average lengths of fish with same numbers of visible annuli but with one group having normal and the other retarded scales, respectively. In other words, the length of normally scaled fish of an age group (x axis) was plotted against length of fish one year older having retarded scales (y axis). A straight line was fitted to the data by the least squares method. The equation was calculated to be: Mean length of normally scaled fish $= -84$ mm. $+ 1.163$x mean length of retarded fish. The upper curve based on lengths of normal fish was included for reference. Average length at n years on the x axis was plotted against length at $n + 1$ years on the y axis. The following equation describes the normally scaled fish: Length at n years $= -118.6$ mm. $+ 1.234 \times$ length at $n + 1$ years.

The vertical distance between the lines represents the mean length difference between fish having normal and retarded scales. The slope value suggests that in the sample of 900 fish, an appreciable degree of growth compensation occurs and the gap in respective lengths decreases each year. No correction was made to compensate for variability in length measurements resulting from the catch being spread over the whole season.

ANALYSIS OF A SAMPLE AGE-FREQUENCY DISTRIBUTION

To illustrate the characteristics of seasonal creel samples, the age-frequency dis-

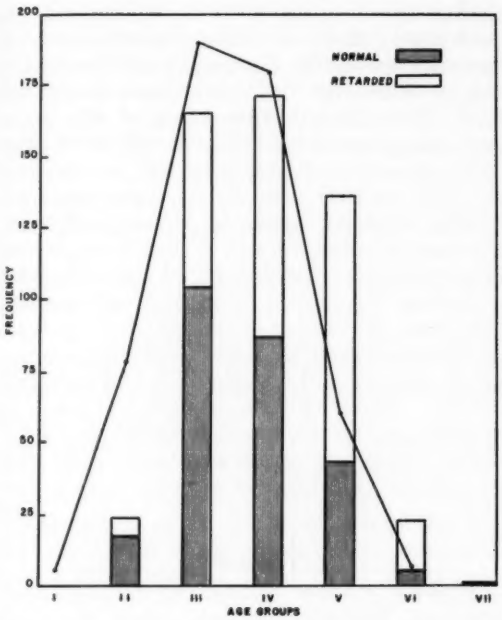

FIG. 14. Frequency distribution of normal and retarded fish in the weekly creel samples at Fishing Bridge Dock. The frequency polygon shows the distribution of the sample when aging was based solely on annulus counts irrespective of the hypothetical normal and retarded types.

tribution of the 1952 weekly collection from Fishing Bridge is shown in Figure 14. The histogram represents the frequency of normal and retarded fish in each age group. The frequency polygon shows the distribution when annulus counts are assumed to represent the correct age of the fish. It is evident that Age-groups III, IV, and V were the chief contributors to the 1952 collection. However, the composition of the catch changed considerably during the fishing season. For example, the Group III trout comprise only 16.5 per cent of the catch during the period up to the middle of July compared with 40 per cent for the remainder of the season. Apparently their vulnerability increased during the season and recruitment was nearly complete at the end of the summer. Fish of Age-group II formed a small part of the total catch but they were six times more numerous during the second half of the season.

During the first half of the season, the Group V fish comprised 32.7 per cent of the creel sample at Fishing Bridge Dock. The percentage declined to 18.8 per cent during the second half of the season. Undoubtedly the percentages were influenced by the location of the dock adjacent to a large area of spawning gravel at the lake outlet of Yellowstone River. A heavy take of gravid fish usually occurs in the early part of the season above and below the bridge and to a varying extent in other parts of the lake. The vulnerability of fish on the redds probably influenced the composition of the sample in June, and to a lesser extent in July. Although Figure 14 indicates that fish in their third and fourth years were incompletely vulnerable, the retarded segment of these age groups demonstrated greater delay in recruitment than did fish having normal scales. About 36.7 per cent of the sample of Age-group III fish had retarded scales whereas there were almost equal numbers of each type in fish a year older. The predominance of retarded fish in the group of five- and six-year-olds in the present sample is year-class phenomenon and will be discussed in connection with Figure 15.

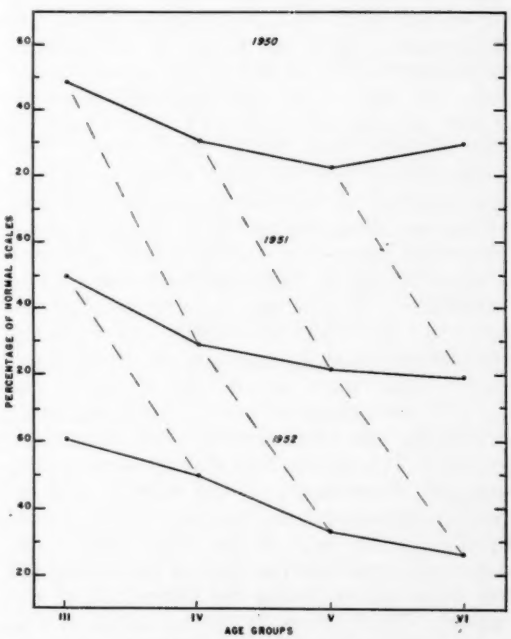

FIG. 15. Percentage frequency of normal scales of various age groups of black spotted trout collected at Fishing Bridge Dock, 1950–52. Broken lines connect points representing percentages of normal scales for individual year classes.

The cause and extent of the decline in percentage of normal types in progressively older fish was studied by analyzing data obtained from scale collections for 3 years at Fishing Bridge Dock. Between 400 and 500 scales comprised each year's sample which was drawn randomly from anglers using rowboats and those fishing from the wider ranging guideboats. The former are restricted to the vicinity of Fishing Bridge while the latter can move farther into the lake. The catch therefore represents fish from a radius of a mile or two from Fishing Bridge, with the bulk obtained from an area within one-half mile of the dock.

The data obtained from age determinations were arranged to permit comparison of the incidence of normal scales in each year class during consecutive years. The broken lines connect points representing percentages of normal scales in each of the four year classes for which age data were available. For example, the broken line beginning with Age-group III in 1951 shows that the percentage of normal scales for the 1948 year class was about 50 per cent and that the percentage of normal types was the same a year later. Agreement within the 1947 year class is not as good; the normal type comprised half the catch as three year olds, but made up only about 30 per cent of the samples as Group IV and Group V fish in 1951 and 1952, respectively. The percentage of normal types in the 1946 year class fluctuated between extremes of 30 and 21 per cent from the fourth to the sixth year. The 1945 year class was about 20 per cent normal during its fifth and sixth years. The available evidence suggests fairly good agreement in percentages of normal scales during successive years in each year class. Two factors may have caused the apparent decline in percentage of normal-type fish with increasing age when several years data were grouped. It appears that during some years, unequal recruitment of the normal and retarded segments of the fish population occurs in the fourth year of life. The 1952 catch data indicated that the bulk of the Group III fish were taken during the latter half of the season. While the early-season catch of this group was predominantly of the normal type, retarded fish constituted an increasing fraction of the catch as the season progressed.

In addition to differential recruitment, as discussed above, the ratio of normal to retarded types appears to be influenced by year-class differences. The preponderance of normal types in the Group III and Group IV fish in 1951 and 1952 collections (Figs. 12 and 15) is largely the result of the high percentage of normal fish in the 1948 and 1949 year classes. The older fish comprising the 1945 to 1947 year classes were predominantly retarded types. As a consequence of unequal recruitment and changing year class characteristics, the combined data showed a gradual decline in occurrence of normal fish from the younger to older age groups. It is anticipated that calculated ratios between normal and retarded fish will expedite routine aging of fish. Further study is needed to determine the applicability of these ratios for supplemental use in the recognition of discrete populations in the lake.

SUMMARY

Fishery studies conducted on cutthroat trout in Yellowstone Lake have required investigation into the technique of age determination. Scales exhibit growth characteristics different from those of the same species in other waters at lower altitudes. The present studies have centered around the identification of scales on which the first annulus failed to form.

Cutthroat trout in Yellowstone Lake ascend spawning streams from May to late July. Fry emerge from late June to early September. Scale formation is initiated when the fish are 41 to 44 millimeters in length. Late-hatched fry may not attain this length before the interruption of growth in October, and thus may overwinter without scales or with only a few small scales. As a result, three developmental types of fry occur in the population: 1) fry overwintering in a fully-scaled state, 2) fry passing the winter partially scaled, and 3) fry overwintering without scales.

Annulus development after the first growing season occurred on the scales of fingerlings whose scale growth had reached the four-circulus stage. Late-hatched fry with rudimentary scales failed to establish a year mark during their first fall and winter period. These fish with "retarded" scales exhibit annulus formation following their second growing season. The term "retarded scale" is proposed to designate a scale that does not exhibit an annulus after the first growing

season, and the word "normal" is applied to a scale which did establish a year mark after one season's growth. Structural criteria have been established for the identification of the two types of scale development. The bases for differentiating the types are:

1. The numbers of circuli before the first annulus,
2. The size of the focus, or first circulus, and
3. The shape and density of the first one or two circuli.

Annulus formation begins before May 1 and is usually complete by the middle of June. Spawners appear to initiate scale growth before non-spawners.

Fingerlings taken late in the season and presumed to be in their first year of life included 35 per cent of fully scaled individuals. Those which were unscaled comprised 22 per cent, and those classified as partially scaled made up 42.7 per cent of the collections. Adults sampled from the 1951, 1952, and 1953 fisheries averaged 40 per cent normal.

LITERATURE CITED

BROWN, C. J. D. and J. E. BAILEY. 1952. Time and pattern of scale formation in Yellowstone cutthroat trout, *Salmo clarkii lewisii*. Trans. Amer. Micros. Soc., **71**: 120–124.

BROWN, C. J. D. and G. D. HOLTON. 1953. Time of annulus formation on the scales of brook and rainbow trout. Trans. Amer. Micros. Soc., **72**: 47–48.

CALHOUN, A. J. 1944. Black spotted trout in Blue Lake, California. Calif. Fish and Game, **30**: 22–42.

COPE, O. B. 1953. Length measurements of Lake Yellowstone trout. Spec. Sci. Report: Fisheries, **103**: 1–17. U. S. Fish and Wildlife Service.

CURTIS, B. 1934. Golden trout of Cottonwood lakes (*Salmo agua-bonita* Jordan). Trans. Amer. Fish. Soc., **64**: 259–265.

FLEENER, G. G. 1951. Life history of the cutthroat trout, *Salmo clarki* Richardson, in Logan River, Utah. Trans. Amer. Fish. Soc., **81**: 235–248.

GOULDEN, C. H. 1952. Methods of statistical analysis. John Wiley and Sons, New York, 2nd Ed., pp. 181–190.

IRVING, R. B. 1953. Ecology of the cutthroat trout, *Salmo clarkii* Richardson, in Henrys Lake, Idaho. Master's Thesis, Utah State Agric. Col. Wildlife Dept.

MOORE, H. L., O. B. COPE, and R. E. BECKWITH. 1952. Yellowstone Lake trout creel censuses, 1950–1951. Spec. Sci. Report: Fisheries, **81**: 1–41. U. S. Fish and Wildlife Service.

ROBERTSON, O. H. 1947. An ecological study of two high mountain trout lakes in the Wind River Range, Wyoming. Ecology, **28**: 87–112.

SMITH, O. R. 1941. The spawning habits of cutthroat and eastern brook trouts. Jour. Wildl. Mgt., **5**: 461–471.

VAN OOSTEN, JOHN. 1929. Life history of the lake herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. U. S. Bur. Fish. Bull. 44 (Doc. 1053): 265–428.

WALFORD, L. A. 1946. A new graphic method of describing the growth of animals. Biol. Bull., **90**: 141–147.

WILLOUGHBY, H. 1951. Age and growth of the cutthroat trout *Salmo clarkii lewisi* in Yellowstone Lake. Yellowstone Nature Notes. U. S. Dept. of Int., Nat. Park Serv. Yellowstone Park, Wyoming, **25**(3): 29–32.

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DETERMINATION OF SEX AND AGE OF SCALED QUAIL

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During a study of scaled quail in western Texas it became necessary to find methods for aging and sexing live-trapped birds. While criteria are available for aging certain galliform birds no previous methods have been established for scaled quail. Likewise, there are no descriptions in the literature of the slight sexual dimorphism in scaled quail.

These studies were conducted in Brewster County, in the Big Bend region of Texas, under Federal Aid Project W-57-R. It should be emphasized that consideration is not given herein to racial differences in plumage characters or to possible geographic differences within the subspecies *Callipepla squamata pallida* which occurs in this area.

We are indebted to the New Mexico Department of Game and Fish which, through the kindness of Mr. Homer C. Pickens, State Game Warden, made known-age chicks available from the State Bird Farm at Carlsbad for our study.

Methods

Studies of plumage characters in relation to sex were made on specimens collected from central Brewster County, Texas, over a two-year period, 1953–54. Measurements, color notes and weights were taken prior to dissection and examination of gonads.

Lacking the time and facilities to study a large number of known-age chicks, much reliance was placed in bobwhite molt data provided by other workers since previous experience had indicated that maturation of scaled quail approximates that of the bobwhite. One objective of this study was to test that apparent homology.

Twleve scaled quail, 29 days old, were obtained from the New Mexico game bird farm. Initially, and approximately at one-week intervals thereafter, these birds were carefully examined and notes were made of apparent plumage changes. At first, measurements were taken in millimeters of the length of growing primaries. Subsequently this was abandoned and visual estimates were made of the approximate fraction of full growth the feathers had attained, based on measurements of full growth on study specimens. Unfortunately seven of the 12 birds were killed by a predator during the study, so the final data regarding primary molt are based on only five birds.

Sex Distinction

It is well known that male and female scaled quail are difficult to distinguish. Many persons working with penned birds have developed enough familiarity with them to tell the sexes, but no descriptions of the differences have reached the literature. The differences described here are distinct and consistent enough for sexing birds in the hand, but it is almost impossible to differentiate birds in the wild.

In examining the plumage of scaled quail of known sex, the most striking and consistent differences between males and females are found on the head and throat region. In males, the plumage on the side of the face is characteristically uniform pearl grey in color, with the exception of the brownish ear patch. The throat normally is clear white just behind the lower mandible, and blends into a yellowish or buffy wash on the lower throat.

In females, the plumage of the side of the face is characteristically streaked, dirty grey in color due to an arrangement of longitudinal black streaks on the ground color of grey or greyish-white. The throat is also streaked, but the ground color is much lighter than that of the face. Often the streaks are less pronounced so that the throat is quite white, but lacking the yellowish wash found in males.

On microscopic examination of the feathers of the face and throat of the female, it was found that each feather has a black central line most pronounced in the terminal half. These feathers, overlayed in series, form the pronounced streaked effect. In males, the same feathers have a faint brown central line, or none at all. Occasionally the males also have these feathers arranged in series so that a faint brown-streaked appearance is noticeable, but the streaks

are very narrow, distinctly brown, and seldom approach the coarse, dark markings of females. In Figure 1 the contrast is shown

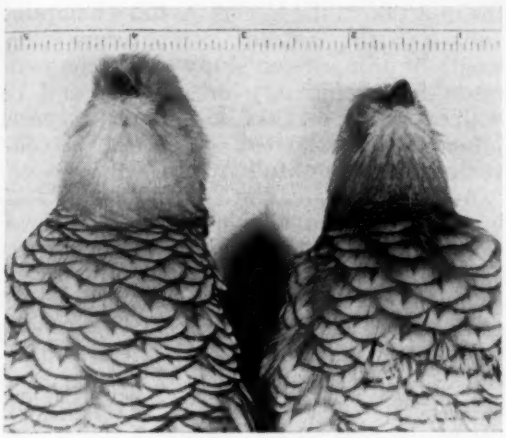

FIG. 1. Male (left) and female scaled quail, showing differences in plumage of the face and throat.

between males and females in regard to face and throat plumage.

After determining these differences, only two errors were made in judging the sex of 64 specimens; both were females erroneously called males. The occasional development of facial streaks in males and the presence of a relatively clear, yellowish throat or smooth grey face in females can account for some error, but the criteria are useable for most practical applications.

In Colorado, Figge (no date) reported difficulty in distinguishing sexes of scaled quail ". . . except during the time of mating, laying, brooding and rearing of young." In a group of 141 January birds, 29 errors in judgment were made, but Figge did not describe the criteria he used. In studying Oklahoma birds, Sanford D. Schemnitz (*in litt.*, November 17, 1954) said that he found our criteria accurate (about 100 per cent in adults, some overlap in juveniles).

In the present study it became difficult, and therefore inadvisable, to differentiate males and females by face and throat plumage during the annual molt. Likewise, in juveniles sex was indistinguishable until near the completion of the post-juvenal molt at about 17 weeks of age. But for all seasons except late summer and early fall these criteria have proved satisfactory.

Other plumage differences between male and female scaled quail have proven to be too variable to be useful. Nevertheless, the differential development of the plume as a secondary sex character seems worthy of discussion. In measuring the plume, held in a normal semi-erect position, from the apex to the last maxillary bristles, it was found that, of 42 specimens of known sex (collected when not in molt), the plume lengths of 19 females averaged 36.8 mm.; those of 23 males averaged 40.6 mm.

Plume measurements of 80 males and 80 females were drawn at random from data on live-trapped birds sexed by facial characters. These data are shown in Figure 2

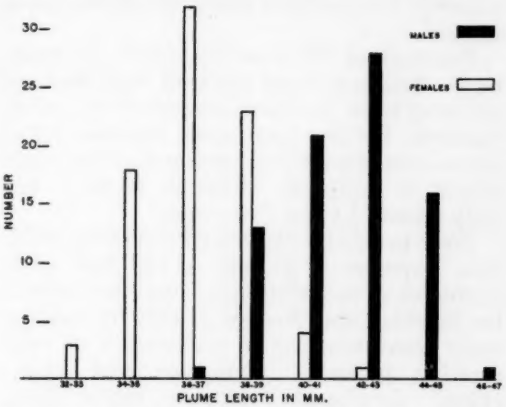

FIG. 2. Distribution of lengths of plumes of male and female scaled quail from a random sample of 160 wild birds.

wherein the plume measurements are grouped in 2-millimeter intervals to compensate for possible errors in measuring and to smooth the curve. In this larger sample, the average length for females was 36.7 mm. with the mode at 36–37 mm. The average length for males was 41.6 with the mode at 42–43 mm.

The differences between the plume lengths of males and females proved highly significant statistically. There also appeared to be a slight tendency for first-year birds of each sex to have longer plumes than older specimens but further sampling to test this observation seems desirable.

AGE DETERMINATION

By the time young scaled quail reach the age of four weeks, the juvenile plumage is almost completely developed and the post-juvenile molt apparently commences shortly before that time, even though full growth

of the juvenile remiges is not completed until the 12th week. Natal down remains around the eyes until the birds are nine or ten weeks of age.

Molting of body feathers is apparent between the 8th and 17th weeks. The "scale" feathers begin to appear on the lateral and dorsal portions of the neck around the beginning of the 9th week. By the 12th week they begin to cover the lower throat and gradually develop posteriorly until the chest and belly are fully scaled by the 16th week. Concurrently the juvenile feathers of the head, face and throat are replaced so that by the 17th week the adult condition is virtually reached and the bird's sex becomes evident.

Feathers of the juvenile plume, or crest, begin shedding about the 10th week and are replaced from the front posteriorly by adult feathers. By the 15th week anterior adult plume feathers are well grown and the adult plume is complete, although perhaps not fully grown, by the 17th week.

POST-JUVENILE MOLT OF PRIMARIES—The time sequence of growth of the first adult primaries of bobwhite quail was determined by Petrides and Nestler (1943) by making daily measurements in millimeters of each growing primary. Thompson and Taber (1948) developed reference tables from which, using the last molted primary as a reference point, salient dates could be located in the lives of young bobwhites, ring-necked pheasants, and Hungarian partridges.

In analyzing the data of Petrides and Nestler, it was explained by Thompson and Kabat (1950) that discrepancies in aging will result from variations in the relative lengths of adjacent primaries. Using a sample of 284 birds they found the standard deviation of such discrepancies to be 3.8 days. However, the value was larger for older birds (maximum standard deviation in the 90 to 104-day-old class, was 4.9 days) and smaller in younger birds. Reasoning that the error in aging would be half the standard deviation, they concluded that age could be judged within 2 days. Reworking their earlier data, Petrides and Nestler (1952) determined a maximum standard deviation of 7.77 days and concluded that most of the errors would fall within plus or minus one week.

In applying this method to known-age birds, the author found that it was impractical to make exact measurements in millimeters either from the leading edge of the wing (as did Petrides and Nestler) or from the insertion in the manus (as did Thompson and Kabat). Instead, comparisons with length of primaries on study specimens were made for preliminary orientation, and in application the stage of development of each primary was estimated to the nearest convenient fraction of full growth.

As mentioned earlier, only 12 chicks of known age were available and seven of these were lost before the study was completed. The observations from these birds were compiled in Table 1 in which the fraction of full growth for each primary is given in tenths at weekly intervals. While it is difficult to estimate stage of growth in tenths, in order to have the relationships reasonably correct for the weekly periods it was necessary to present the data in relatively small denominations. Table 1 was constructed by interpolation to even weekly intervals from the dates on which observations were actually made.

The data indicate that the inception of post-juvenile molt of the primaries in scaled quail may be slightly earlier than in the bobwhite, but the culminating date is approximately the same; that is, 150 days. Comparison of the lengths of primaries of scaled quail with those given by Petrides and Nestler (1943) for bobwhite, revealed great similarity in the earlier stages, but greater disparity at later ages. This condition results because the scaled quail's primaries are longer at full growth. For example, at 40 days Primaries I and II averaged 50 and 37 millimeters, respectively, while in the bobwhite they averaged 43 and 27 millimeters. Referring our measurements to the table given for bobwhite would have resulted in an error of 3 days, which is not excessive. However, at full growth these primaries were 89 and 94 millimeters long on scaled quail; 78 and 83 millimeters on bobwhite.

APPLICATION OF MOLT DATA TO WILD BIRDS—The molt table (Table 1) was applied in the fall of 1954 in aging live-trapped wild birds. When growing birds were trapped more than once, it was possible to check the actual time-lapse against the indicated difference in age from the table. This was possible with 32 individuals in which the

TABLE 1.—TIME SEQUENCE OF THE POST-JUVENILE MOLT OF PRIMARY FEATHERS IN SCALED QUAIL

O = juvenile primary shed, adult primary not yet emerged.
S = quill of new primary emerged with vane still completely enclosed in quill.
2/10 = relative length of growing primary compared to full growth.
F = primary fully grown; full length is measured from the insertion.
// = boundary between juvenile and adult primaries.

Age in weeks	Primary number									
	X	IX	VIII	VII	VI	V	IV	III	II	I
4	S	S	5/10	F				/ O /	S	S
5	S	3/10	8/10					/ S /	2/10	5/10
6	2/10	5/10	9/10				/// /	3/10	5/10	8/10
7	4/10	7/10	F				/ S	5/10	9/10	F
8	6/10	9/10				/// / O /	2/10	9/10	F	
9	7/10	F				/ S /	7/10	F		
10	8/10					/3/10	9/10			
11	9/10				/// / S	6/10	F			
12	F			/// / O /	3/10	8/10				
13				/ S /	7/10	F				
14				/3/10 /	9/10					
15				/5/10	F					
16			/// / O /	7/10						
17			/2/10 /	9/10						
18			/5/10 /	F						
19			/7/10 /							
20			/8/10 /							
21			/9/10 /							
22			/ F							
Average full length (millimeters)	91	100	108	109	108	107	105	92	86	81

difference between trapping dates varied from 4 to 57 days. The discrepancies between the actual intervals elapsed and those obtained from the table were distributed as follows:

	Plus								Minus								
Error (days)	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8
No. of birds	1	1	1	3	2	2	0	3	4	6	1	1	1	1	2	0	0	3

All of the errors which exceeded seven days were made in cases where the actual time-lapse was three weeks or more.

Considering that normal variations occur between individuals of equal age, between the relative growth of adjacent primaries, and between the stage of development of left and right wings, plus the difficulty of making exact measurements of primaries

on live wild birds, it would seem undesirable to attempt to reduce the tolerance limits to less than one week. Furthermore, in back-dating to nesting and hatching periods for use in ecological correlations, it should be realized that few, if any, factors can be isolated from the phenological complex as having an influence restrictable to plus or minus one week.

AGE CRITERIA IN ADULTS—After the post-juvenile molt is completed, first-year scaled quail closely resemble older birds. They can be distinguished most conviently, as discussed by Leopold (1939), by the primary coverts. In a first-year bird the outer two coverts are usually plain grey as in adults, while the remainder are tipped, edged, or mottled with white or tan. These coverts are completed before the juvenile primaries are fully grown and are retained through the post-juvenile molt. In the first post-nuptial molt, approximately at the age of one year, the juvenile coverts are lost and replaced by solid grey adult coverts. Only eight primary coverts are developed appreciably in scaled quail; the inner two are absent or so small as to be easily overlooked.

In the post-juvenile molt the outer two juvenile primaries (numbers IX and X) are retained and are distinguishable from the new adult grey primaries in being browner in color. The first post-nuptial molt is complete through these outer two primaries. One adult bird was trapped which apparently retained juvenile primary number X into the second year, but no wild birds were found which shed the ninth or tenth primary in the post-juvenile molt. However, in the penned birds, three cases occurred in which one (or both) of the outer primaries was replaced by a new feather after the juvenile feather was lost apparently by accident.

Differences in the form of the tips of adult and first-year primaries, mentioned by Leopold (1939), are so small in scaled quail that they are not useful in age distinction. However, the primary coverts are so obvious that there is no need for further criteria to distinguish first-year birds from older ones.

The time of inception of the post-nuptial molt in relation to breeding activity has not been reported for any of the quails. Kabat, *et al.* (1950) found that in ring-necked pheasants the primary molt stage of a hen is closely associated with the date of hatching of her brood. Such studies are needed for scaled quail because much phenological data are lost in the inability to back-date to breeding phenomena from the stage of molt of adult birds.

LITERATURE CITED

FIGGE, H. J. (no date). Progress report of research and management of scaled quail in Colorado. Colorado State Game and Fish Dept., 12 pp. mimeo.

KABAT, C., D. R. THOMPSON and F. M. KOZLIK. 1950. Pheasant weights and wing molt in relation to reproduction with survival implications. Wis. Cons. Dept., Tech. Wildlife Bull. No. 2.

LEOPOLD, A. S. 1939. Age determination in quail. Jour. Wildl. Mgt., **3**: 261–265.

PETRIDES, G. A. and R. B. NESTLER. 1943. Age determination in juvenile bobwhite quail. Amer. Midl. Nat., **30**: 774–782.

———. 1952. Further notes on age determination in juvenile bobwhite quails. Jour. Wildl. Mgt., **16**: 109–110.

THOMPSON, D. R. and R. D. TABER. 1948. Reference tables for dating events in nesting of ring-necked pheasant, bobwhite quail, and Hungarian partridge by aging broods. Jour. Wildl. Mgt., **12**: 14–19.

THOMPSON, D. R. and C. KABAT. 1950. The wing molt of the bob-white. Wilson Bull., **62**: 20–31.

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SNOW DEPTHS AND UNGULATE ABUNDANCE IN THE MOUNTAINS OF WESTERN CANADA

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It is long established that "severe winters," or "hard winters," cause fluctuations in ungulate populations. Annual reports of the British Columbia Game Department have noted since 1912 that such winters may cause serious declines. Roe (1951) reports "hunters' traditions" as early as 1875 attributing bison decreases on the American prairies to severe winters.

Published accounts of ungulate mortality due to severe winters or deep snow involve a wide range of species in a large geographic area. Holzworth (1930: 23) notes that black-tailed deer on the islands of southern Alaska die in thousands during severe winters. Spiker (1933) considers deep snow as the only important factor in winter mortality of Adirondack white-tails. Rand (1947) concludes that severe winters with deep snow are the worst enemy of pronghorn antelope in Alberta. Murie (1944) records heavy losses in Dall sheep, and in moose, during severe winters with deep snow in Alaska. Roe (1951) quotes numerous historic references describing American bison declines because of snow, but discredits most of them in support of his thesis that man, not snow, was the bison's chief enemy. Cowan (1950) records a cold winter with deep snow that reduced mountain goat survival in the Canadian Rockies, and later (1952) calls winter the greatest enemy of goats. The latter paper also postulates the near extermination of elk in the Rocky Mountain region as a result of severe winters in the 1870's and in 1898, while Banfield (1949) describes an elk die-off in Manitoba because of severe winter conditions. Longhurst *et al.* (1952) show that deer die-offs in the Sierras of California have occurred mainly in years with heavy snowfall. Matthews (1952: 290) describes red deer declines in the Scottish highlands during severe winters. Wildhagen (1952) notes winter declines of reindeer in Norway, here possibly due to lichen ranges being covered with ice.

The pioneer detailed study of snow-ungulate relationships appears to be that of Severinghaus (1947). He showed that deer mortality in the Adirondacks of New York "varies from year to year with the severity of the weather" and that "deep snow is the principal weather factor involved."

From California to Alaska to New York, in a large part of North America subject to cold winters and frozen precipitation, no ungulate seems immune from the effects of winter with its snows, perhaps excepting caribou. This exception may exist more from lack of data than from lack of occurrence, as information from Norway suggests and as this paper will further support.

Methods of Study

This study had three parts. The first compared trends in average annual depths of snow with trends in the numbers of various ungulates. Data on ungulate populations were obtained from the annual reports of the British Columbia Game Department (Anon., 1909 to 1950). Weather data were gathered from the monthly reports of the Canadian Department of Transport (Anon., 1928–1950), and from the 1935–1952 Summary of Snow-survey Measurements in British Columbia (Anon., 1952). Data on snow depths are not common. Few weather stations in British Columbia have kept continuous readings of snow depths on the ground, and only three stations have data extending as far back as 1928. Snow-survey stations provide valuable data, but only a few have measurements dating from 1935.

Field work was the second phase of study, observing ungulate populations in selected areas (mainly in provincial parks), and interviewing observant people who knew the areas concerned.

The third and final phase was to examine wildlife literature for Alberta and Alaska to determine if conclusions reached for British Columbia applied to a greater area.

[1] I. McT. Cowan and R. W. Ritcey gave valuable assistance, commenting upon an early form of this paper.

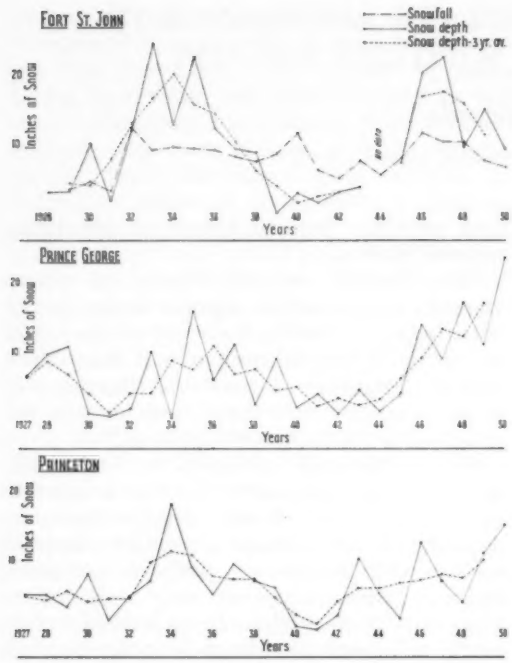


FIG. 1. Average monthly snow depths from three meteorological stations in British Columbia, with snow fall averages of monthly totals from one station. (Data from Canadian Dept. of Transport.)

SNOW DEPTHS IN BRITISH COLUMBIA

Trends in snow depth in British Columbia are shown in Figure 1. These data are from snow depth readings taken on the last day of each month. Points shown represent average monthly snow depths for the six months October to March inclusive, and each figure is plotted over the year of the last three of these months (*i.e.* winter of 1934–35 is plotted over 1935). The curves represent both annual averages and the results of smoothing these by three-year averages. The curves for Fort St. John show also average monthly snow precipitation. The difference possible between snow depths and snow falls in the same place is here evident.

Three localities are represented, Princeton in the dry grasslands of the south, Prince George in the spruce-balsam forests of the central part of the province and Fort St. John in the aspen parklands of British Columbia's "Peace River Area," east of the mountains and close to Alberta (Fig. 3). Two facts are evident from these curves. First, deep snow years and shallow snow years tend to be grouped into periods. For example, the periods 1933 to 1938, and from 1946 to the early 1950's may be designated as times of deep snows, while the period 1940

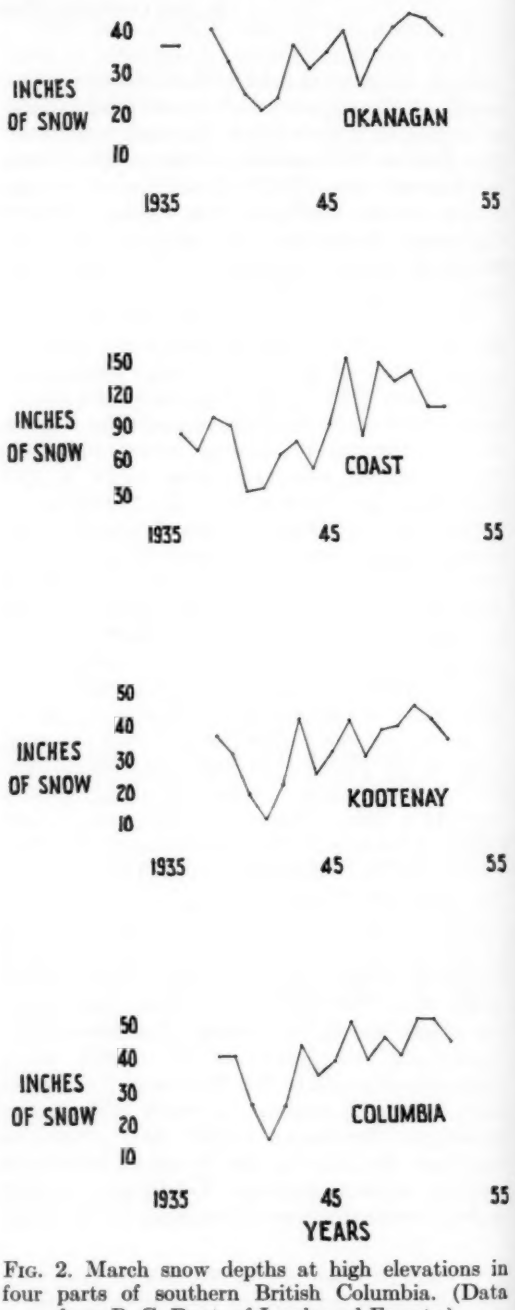


FIG. 2. March snow depths at high elevations in four parts of southern British Columbia. (Data from B. C. Dept. of Lands and Forests.)

to 1944 is one of shallow snows. Second, the curves show reasonably similar trends for the three places. There is evidence here that annual snow depth trends are similar over a large part of the province.

Provincial snow survey readings provide additional data. Figure 2 is based on these readings, and shows snow depth curves for four parts of southern British Columbia from 1935 to 1952. Each curve represents the average from five snow stations. The locations of these four regions are shown in Figure 3. All readings were taken at high

FIG. 3. Location of three meteorological stations and four regions supplying data for Figs. 1 and 2. Hatched areas are: 1—Coast; 2—Okanagan; 3—Columbia; 4—Kootenay. Dots in hatched areas indicate snow measurement stations.

elevations, usually in sub-alpine forest or above, and figures used are for the end of March which is considered by the office concerned with these measurements to be the end of the snow accumulation period. These four curves are similar in that they show a period of shallow snows about 1940 with increasing snow depths thereafter. Only deep snows in 1943 destroy evidence of progressively increasing snow depths through years in the middle 40's. Deep snows did not occur at lower elevations in 1943 (Fig. 1).

A shortcoming of all snow data used here is that they are not from winter ranges, nor even from winter range elevations, but are either from towns on the valley bottoms or from high elevations. Snow depth trends should be much the same regardless of elevation, but there can be exceptions. In the past winter (1953–54) snow depths were the deepest in at least eight years at sub-alpine elevations in the Cascade Mountains, yet twenty miles away and 1500′ lower deer ranges had the shallowest snow since the middle 1940's.

UNGULATE FLUCTUATIONS IN BRITISH COLUMBIA

Annual reports of the British Columbia Game Department provide a continuous source of information on game abundance in past years. These, from 1909 to the present, contain annual statements on game abundance applying variously to the whole province or to relatively restricted areas. In analysing these reports all statements of ungulate abundance were noted, and from these statements of declines, or of low population, were segregated. Figure 4 shows these

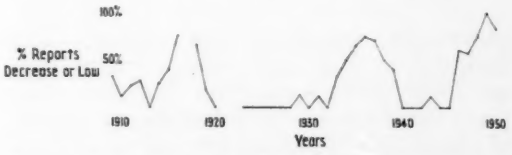
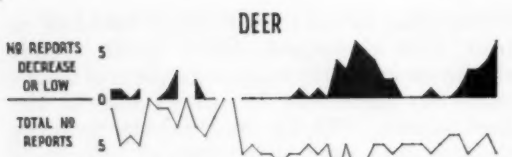
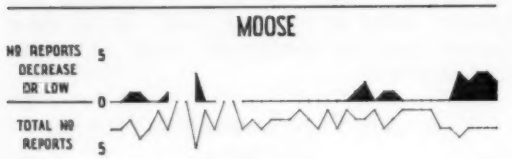


FIG. 4. Percentage of reports on deer, moose and caribou abundance reporting decreased or low populations. (Data from B. C. Game Dept.)

data applying collectively to deer, moose and caribou, wherein the number of statements of decline and low numbers are expressed as a percentage of the total number of abundance statements for each year. This method can show only trends, and some other limitations should be noted. It gives equal weight to statements covering areas of different size. In addition there is clear evidence in several reports of reluctance to report game declines. One reporter, for instance, after reporting increases for three years and reporting nothing useful in the fourth year, in the fifth year declares that "deer are again coming back." There can be no doubt, however, that in the aggregate these reports have caught the main trends of game populations from year to year, and it is trends that are of major concern here. Figure 4 suggests that there have been





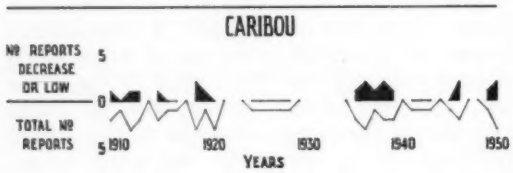


FIG. 5. Number of abundance reports compared with number of reports of decreased or low population. (Data from B. C. Game Dept.)

periods of abundance and scarcity, and Figure 5, in which deer, moose and caribou are dealt with separately, indicates that these three species have had similar trends of abundance. The data for caribou are not complete, but are at least highly suggestive.

In addition, these annual reports give information on mountain sheep in the so-called Cassiar country, roughly the north west quarter of the province. For some reason there were more reports from this remote region before the first war than there have been since. The sequence of reports, 1909 to 1919, shows that the Cassiar thinhorn sheep have followed the same trends as deer, moose and perhaps caribou in this period.

Mountain goats have been mentioned only nine times, with scarcity or decline noted twice, in 1946 and 1949.

Elk are mentioned fourteen times and reported as decreased only in 1909.

It is evident, then, that most ungulates in British Columbia declined in numbers at the time of the 1914–18 war, in the late 1930's and again in the late 1940's. There also appears to have been a period of scarcity just prior to 1909 for reports in that year note moose as "scarce until the past few years" but rapidly increasing, caribou had disappeared from the Itcha Mountains but otherwise were increasing, elk had suffered some mortality recently, and the Cassiar sheep were down. By 1910, white-tailed deer in southern British Columbia showed "extraordinary increases" after they "seemed doomed a few years ago," moose in the Fernie District were "gradually coming back" and deer in the Columbia valley were "more numerous than for years."

Between periods of scarcity there was notable abundance, most evident, of course, in the more common lowland species of the agricultural south. In these years there were numerous reports like "increasing rapidly" and "more plentiful than at any time in the memory of oldest residents."

Brian Williams, former Game Commissioner in this province, has also documented periods of scarcity and abundance, but he was regrettably unconcerned about dates. He states (1925) of mule deer that at the time of writing they were scarce, partly as a result of lack of protection during the war, but also because of cougars and coyotes. Previously there had been a time of abundance with heavy damage to agricultural crops. Before this, scarcity was general, and he explains the low numbers as due to market hunters, spread of civilization and Indians. Prior to this, again, "the whole of the dry interior simply swarmed with mule deer." In another book (1935) he records a "tremendous increase" in late years. This sequence is not easy to follow because of lack of dates, but deer scarcity is evident during the 1914–18 war and after it, with periods of abundance before and after. This much supports conclusions from Figures 4 and 5. Working back, there was another period of scarcity near and perhaps just after the turn of the century. Prior to this again, they "simply swarmed."

The evidence seems conclusive that ungulates in British Columbia have had successive periods of marked scarcity and abundance.

The curves for snow depth and ungulate abundance are similar for the twenty-year period in which snow data are available. Both show highs in periods of several years about the middle 1930's and late 1940's with a period of low values between. Close examination shows that high values in the ungulate curve are a few years later than in

the snow curve. This is to be expected. The ungulate curve represents reports of decrease and low population. Ungulate scarcity would continue for several years after removal of the factor causing it.

FIELD WORK

While data on snow and population trends described above end in 1950, field work begun in 1949 brings the situation to the present and substantiates some of the data already given. This information is given in condensed form below. References to winters dated by a single year indicate the winter ending in the first half of that year. Places referred to are shown in Figure 6.

FIG. 6. Ten areas from which field data were gathered. 1—Tweedsmuir Park; 2—Sayward Provincial Forest; 3—Mount Seymour Park; 4—Southern Vancouver Island; 5—Manning Park; 6—Ashnola Region; 7—Vavenby Region; 8—Wells Gray Park; 9—Mount Robson Park; 10—Bowron Lakes Region.

Mule deer in Manning Park were numerous in 1946. The winters 1947–8–9 had deep snows and deer decreased in abundance. By 1952 recovery of numbers was evident and there was increasing abundance to 1955. Similar trends were noted in the Ashnola drainage, Wells Gray Park, Mount Robson Park and near Vavenby. Black-tailed deer populations behaved similarly in the Sayward Forest and southern Vancouver Island. Recent increases are evident also in Seymour Park on the mainland coast, but here the decline appears to have taken place in 1943, coinciding with a year of deep snows at high elevations (Fig. 2).

Moose in Mount Robson Park declined in numbers through the period 1948–9–50, and had recovered appreciably by 1952. Deep snows accompanied the declines. Similar trends were noted about the Bowron Lakes. In Wells Gray Park there was no serious die-off, but through these winters with deep snow moose were concentrated on the lower ranges to an extent not observed since.

Mountain caribou were decreased in Wells Gray Park by 1935, appeared to be especially scarce after 1945, then showed an apparent increase after 1952. There was a decline in Tweedsmuir Park and about the Bowron Lakes in the 1930's, with reports of increased abundance in the former in 1954 and 1955 suggesting a more recent decline. In Mount Robson Park there was a decline in 1945 or 1946, while increases were evident by 1952.

In Mount Robson Park and vicinity bighorn sheep declined an estimated 85 per cent through the winters 1948–9–50, and there was an elk die-off in Yellowhead Pass in 1949. Both species have increased since. Mountain goats in 1953 were still not recovered from a decline which occurred after the mid-1940's.

These data substantiate the curves in Figures 4 and 5 and extend our knowledge to the present. From all this information a pattern is evident, naturally best documented for deer which are most abundant and most closely associated with man at lower elevations, and poorly recorded for the wilderness species and those less widely distributed. There were periods of ungulate scarcity in the 1900's, 1910's, 1930's and 1940's with alternate periods of abundance. British Columbia is now experiencing such abundance, especially evident in deer from the Pacific slopes to the Rockies. The record of snow depths through these years of abundance is one of relatively snowless winters. It has long been known that deep snows may cause severe mortality in some ungulates, but the light cast by these data leaves no serious doubt that years of deep snow and scarce ungulates, and years of shallow snows and ungulate abundance, are both grouped into alternating periods of years. Further, all ungulates seem to be affected, although the data is admittedly inadequate

for final conclusions for mountain goats, and perhaps caribou. Studies elsewhere have demonstrated severe effects from deep snow upon herds of mountain sheep and elk, substantiating conclusions from limited data in this study.

UNGULATE POPULATION TRENDS IN ALBERTA AND ALASKA

The purpose here is to briefly survey pertinent literature on ungulate populations in Alberta and Alaska to determine if there is indication of correlation with ungulate fluctuations in British Columbia.

Hewitt (1921) records a peak moose kill in Alberta in 1914, with a decline after the 1914–18 war. He also notes an increasing deer kill from 1907–14, and a decline from 1914–18. These indications of peak numbers in moose and deer in 1914 are in agreement with British Columbia data, but the effect of war upon the harvest is an alternative explanation.

Rand (1947) studied the history of pronghorn antelope in Alberta, and concluded that "bad winter weather is the worst enemy." Twelve cases of severe winters affecting antelope populations are recorded, five in 1906–7, five in the two winters 1935–6 and 1936–7, and two in 1944–5 (the data were gathered in 1945). The similarity of these mortality periods to those in British Columbia is marked. An absence of die-off reports during the 1914–18 war is noteworthy.

There is more published data on Alaskan ungulates, and some of them do not agree well with British Columbian information.

Williams (1952) presents some fragmentary data on deer numbers in south-eastern Alaska. There was a serious die-off in 1918, peak numbers in 1929, and a die-off in 1930.

Murie (1944) reports a Dall sheep die-off in the severe winter of 1928–29, after a peak population in 1928. A more severe die-off occurred in 1931–32. Scott *et al.* (1950) extend the record, reporting a decline through the first half of the 1940's and an increase in the last half.

Murie (*op. cit.*), for the Mt. McKinley area, reports moose scarce in 1922 and 1923, increased in 1927 and 1928 and decreased in the winter of 1931–32. Chatelain (1950) reports a peak moose population in 1925 and Spencer and Chatelain (1953) note declines, some of them minor, in 1913, 1916, 1922–23, 1936 and 1946. The last two papers refer to the Kenai Peninsula.

These Alaskan records are not similar to data from British Columbia. Die-offs of deer and sheep in the early 1930's and the trends of sheep populations in the 1940's do not coincide with major periods of decrease in British Columbia. Moose data also have dates not in agreement.

Recent publications by Scheffer (1951) and Leopold and Darling (1953) give detailed information on the rise and fall of the reindeer industry in Alaska. Reindeer are domesticated, it is true, but they are dependent upon wild ranges, and hence are subject to many influences affecting wild populations. Scheffer (*op. cit.*) shows that the peak was reached on the Pribilof Islands in 1938, and the major decline took place in 1939 and 1940. Leopold and Darling (*op. cit.*) report a die-off at the base of the Kenai Peninsula in the winter 1938–39. The same authors show figures for the entire Alaskan reindeer population indicating peak numbers in 1932, slightly reduced numbers by 1936 and a decline halving the population by 1940. By 1949 the total had dropped to 32,623 from the 1932 high of 625,000 or more. The first part of the reindeer crash occurred during or just after the ungulate declines of the middle and late thirties in British Columbia.

Analysis of all data for Alaska shows that about half of the die-off periods fall, wholly or in part, into the British Columbia die-off and low population periods. This does not appear to be significant.

DISCUSSION

It has been shown that years with deep snow and years of ungulate declines and low population tend to occur in groups, and these data indicate that deep snow periods are also periods of decreases in ungulate populations. In British Columbia, deep snow appears to be a major factor controlling the abundance of mule deer, black-tailed deer and moose. Less adequate information indicates that caribou, mountain sheep, white-tailed deer, elk and mountain goat are similarly affected. The data is more fragmentary than might be desired, the period of time under study is really quite short, but the evidence is remarkably clear-cut as far as it goes.

While snow depth appears to be a major

factor in the winter survival of ungulates there are undoubtedly other complicating factors. The abundance of food and cover, operating singly or together, could be major factors either increasing or decreasing the effect of deep snow.

It has been noted that moose in Wells Gray Park did not decline appreciably during the deep snow period of the late 1940's. By contrast during this same period of severe winters there were general moose declines throughout central British Columbia (Hatter, 1949). The failure of snow to seriously reduce the Wells Gray population is probably the result of the range being understocked relative to most good ranges in the province. Moose were late in arriving on the Wells Gray range. They appeared first in the early 1930's, and although numerous by the late 1940's, snows did not restrict travel and bury food to the extent that heavy mortality occurred. It is noteworthy that Spencer and Chatelain (1953) report that in the Susitna Valley of Alaska, moose appeared later than on some ranges where there have been die-offs, and the Susitna herd has had no large winter kills.

The operation of cover in offsetting the effect of deep snows was demonstrated on Vancouver Island in the late 1940's. Black-tailed deer flourish on large areas clear-cut and often burned by loggers. The type of logging practiced in the Sayward Forest is typical and here left square miles without standing trees, except in swampy areas and on thin outcrop soils atop hills. During the die-off period surviving deer inhabited these small and scattered patches of timber. The open slashings had food in abundance, but much of it was buried and the snow was so deep that the animals floundered in it. Recently these same areas have been relatively snowless and deer in a few years have become more abundant than they were before the decline. By 1950 a series of deep snow years had reduced the population alarmingly, but by the spring of 1952 it was easy to see over one hundred deer in a short evening road count.

One may conclude that food and cover can modify the effect of snow, and that the response to potentially similar snow conditions may be very different on different ranges.

It has been noted above that deep snows have been recognized as a factor in ungulate mortality for a long time and over a large area. Even casual observation can detect such mortality. It seems, however, to have been regarded as an occasional phenomenon rather than the major and recurring condition that it is. While Williams (1925) partially understood the affects of deep snow upon deer, and he clearly describes a series of periods of deer scarcity and abundance in British Columbia (see above), he suggests a long list of reasons for the die-offs which include market hunters, encroaching civilization, Indians with new repeating rifles, coyotes, cougars and lack of protection during a war. Similarly, in the annual reports of the Game Department many reasons are offered for ungulate decreases which occurred during deep snow periods. Severe winters and deep snow are often mentioned as partial factors, but wolves, cougars, coyotes, Indians, dry summers, ticks, hunters and railway gangs are often regarded as more serious. The interesting point is that nearly all of these supposed causes of disaster occurred in deep snow years. One can only conclude that while these diverse factors may have had their local importance, it is improbable that they caused the widespread declines observed. It requires some widespread phenomenon, like weather, to set so vast a stage as an entire province. Perhaps we must look upon ungulate declines as having primary and secondary, even tertiary and quaternary causes. Whether the animals die of starvation because of snow, of ticks because of near starvation, or by cougars because of ticks, the basic cause may be the same. Perhaps the real cause of ungulate scarcity in the past has been obscured by its more obvious associates.

Murie (1951) has pointed out that most efforts in ungulate management have attempted to maintain stable populations. His suggestion is that artificially induced fluctuations will better maintain our ranges. In British Columbia, on the other hand, our management efforts have been based upon a stable population concept while the animals have fluctuated in spite of us. The situation has been not unlike that of grouse management in the past. While grouse rose and fell with a certainty akin to the seasons, we blamed anything handy for the declines and praised our legislative wisdom during periods of increase and abundance.

Reactions to these ungulate fluctuations

in the past have been anything but consistent. In areas where our criterion of abundance was the condition of range, heavy range use during deep snow years has led to diagnoses of overabundance. Resulting recommendations were heavier cropping. In areas where peculiarities of vegetation and range made actual counts of animals the best indication of abundance, declines in population have led to closed seasons so herds could recover. With the tools at hand both conclusions appeared logical at the time, but the possibility of having called two similar situations black in one case and white in another is all too apparent.

Where ungulates are under management for the hunting public, management action must change with the changing population. The crop should be heavy during periods of plenty. There is no more point in trying to stockpile deer than in trying to do so with fluctuating grouse. But population increases should be allowed, if indeed they can be prevented. If our aim was to hold populations at severe winter levels and our management should succeed in doing so, the resulting loss of good hunting could be greater than the loss due to die-offs. In addition, this study suggests that deep snow periods may be predictable to a degree and on a short term basis, for deep snow years tend to group. Early indications of entering a deep snow period may justify attempts to reduce herds, for a die-off is coming in any event.

Die-offs accompanied by heavy range use do not necessarily indicate a chronic condition of overpopulated range. At best a die-off indicates a temporary reduction of necessary range resources due to weather; at worst it brings about a major and permanent decline premature to when it would have come if severe winters had not occurred. This last, for instance, could be part of the cause of reindeer declines in Alaska in the late 1930's where overgrazing had, or had nearly, set the stage for a crash in any event. This is speculation, however, and is not supported by first hand information.

Mountain caribou in Wells Gray Park may have declined in a manner similar to these reindeer. A previous report (Edwards, 1954) indicates that this decline may be due to fire destroying winter range forests at low elevations. A major fire swept these valleys in 1926, and there were smaller fires of importance between that date and 1940. The first indication of caribou decline was noted in 1935, but it was not generally appreciated until two years later. It may be more than coincidence that the decline occurred in deep snow years. While range reduction by fire was probably a major cause of the decline, deep snows may have brought the full impact of range reduction into operation.

Consideration of deep snow periods also casts some doubt upon past analyses of ungulate-range relationships. Two ranges which appear to have the same resources in autumn, and therefore might be expected to winter equal numbers of animals, will in reality support very different populations if one has shallow snow, the other deep snow. This is almost self evident, but when dealing with the same range in different years the situation may be similar, seriously complicating attempts to estimate in autumn the amounts of forage or browse available in the coming winter. Again, in mountainous terrain at least, years of deep snow tend to concentrate ungulates at the lower elevations. Browse or range surveys in deep snow periods are likely to uncover "overuse of range" in these periods. But are such ranges over-stocked? Several years later the same herd, considerably increased in size, may be using the same winter range which has expanded into higher elevations because of snowless winters. There may then be much lighter use per unit of range. This condition has been noted on the winter range of the Wells Gray moose herd. The solution appears to be range surveys over a period of time, determining use levels with due regard for changes in winter range size.

Thus proper harvests in deep snow years are a matter for determination on each range. With the knowledge that die-offs may result from weather conditions that are temporary and that winter range overuse may be temporary and involve only part of a range, the choice of cropping lightly to ensure maximum survival to more favourable winters, or cropping heavily to further reduce the herd and protect those parts of the range in use, depends upon the area and quality of unused parts of the range which will be used when snow conditions change.

Most of this discussion has been more theoretical than might be apparent. In British Columbia we can apply these management principles locally, but in view of

the fluctuations which our ungulate populations have shown to the present time, apparently as influenced by winter weather conditions, there is some doubt that human harvests have had much influence upon ungulate abundance. There may be local exceptions, but one must conclude from the province-wide picture that our hunters have not been the efficient influence upon ungulate abundance that some would have us believe. The hunting public has hunted populations controlled in the long run by the size and excellence of our winter ranges and in the short run by the degree to which variable winter weather reduced the necessary resources on these ranges. As long as ungulate herds can increase rapidly from the effects of winters with deep snow, weather, not hunting, is the more important control over their numbers.

A different facet of the role of snow in ungulate management in mountainous terrain concerns human influences upon small areas of land essential for ungulate survival in winters with deep snow. These areas are usually on warm slopes at low elevations where most subject to the influence of man. Farming may result in range destruction, while livestock grazing, logging, fire and other influences may have equally drastic effects. Ungulate herds which populate large areas under favourable weather conditions may be exterminated if these small and only occasionally essential ranges are not available when needed. This appears to partly explain the disappearance of bighorn sheep from the rims of dry valleys in southern British Columbia. Agriculture simply crowded them from emergency winter range. A number of mule deer herds have been similarly affected, and the process is continuing. This trend is difficult to combat because the situation is not easy to see. There may be long periods of years without sufficiently severe winters to make these areas essential for survival. As a result, destruction of emergency range may not seriously affect the ungulate population using it for many years. This may have happened to the herd of caribou in Wells Gray Park, discussed above, which may still have adequate winter range for most winters, but which may not have range for high survival in severe winters.

Fluctuating snow depths and peculiarities of terrain may decree that a few acres are the key to adequate stocking over many square miles. The obvious solution is public acquisition of these key acres to ensure the maintenance of the public ungulate resource.

SUMMARY

There have been alternating periods of deep snow winters and shallow snow winters in British Columbia. Population declines in ungulates have occurred in deep snow periods. The record is most complete for mule and blacktailed deer and moose, but other species appear to have shown similar fluctuations.

Limited information from Alberta and Alaska indicates that the former has experienced similar weather and ungulate fluctuations, while the latter shows no conclusive agreement.

Ungulate declines in the past have been blamed on a long and varied list of supposed causes. Snow depths may be the primary cause of a number of factors observed in winter mortality of ungulates.

The seriousness of declines due to snow may vary with the ranges concerned. What appears to be over-use in deep snow years may involve only a small part of the range used at other times.

In British Columbia the record of ungulate fluctuations indicates that the human harvest is not a major population control, at least on the more common species.

Public acquisition of small areas of low elevation winter range may be essential to ensure ungulate abundance over many square miles.

LITERATURE CITED

ANON. 1909 to 1950. Reports. Provincial Game Commission. Prov. of British Columbia. Victoria.

ANON. 1928 to 1950. Monthly Reports. Meteorological Observations in Canada. Dept. Transport. Toronto.

ANON. 1952. Summary of snow-survey measurements in British Columbia, 1935 to 1952 inclusive. Dept. Lands & Forests, Victoria.

BANFIELD, A. W. F. 1949. An irruption of elk in Riding Mountain National Park, Manitoba. Jour. Wildl. Mgt., **13**: 127–134.

CHATELAIN, E. F. 1950. Bear-moose relationships on the Kenai peninsula. Trans. N. Amer. Wildl. Conf., **15**: 224–233.

COWAN, I. McT. 1950. Some vital statistics of big game on over-stocked mountain range. Trans. N. Amer. Wildl. Conf., **15**: 581–588.

———. 1952. Big game of the mountain province. Canada. Geog. Jour., **44**: 226–241.

EDWARDS, R. Y. 1954. Fire and the decline of a mountain caribou herd. Jour. Wildl. Mgt., **18**: 521–526.

HATTER, J. 1949. The status of moose in North America. Trans. N. Amer. Wildl. Conf., **14**: 492–501.

HEWITT, C. G. 1921. The conservation of the wildlife of Canada. Scribner's. N. Y.

HOLZWORTH, J. M. 1930. The wild grizzlies of Alaska. Putnam's. N. Y.

LEOPOLD, A. S. and F. F. DARLING. 1953. Wildlife in Alaska. Ronald Press. N. Y.

LONGHURST, W. M., A. S. LEOPOLD and R. F. DASMANN. 1952. A survey of California deer herds, their ranges and management problems. Calif. Dept. Fish and Game, Game Bull. No. **6**: 1–136.

MATTHEWS, L. H. 1952. British Mammals. Collins, London.

MURIE, A. 1944. The wolves of Mt. McKinley. Natl. Parks Fauna Ser. No. **5**.

MURIE, O. J. 1951. The elk of North America. Wildl. Mgt. Inst. Washington.

RAND, A. L. 1947. The 1945 status of the pronghorn antelope, *Antilocapra americana* (Ord), in Canada. Natl. Mus. Canad. Bull., No. **106**: 1–34.

ROE, F. G. 1951. The North American Buffalo. Univ. Toronto Press.

SCHEFFER, V. B. 1951. The rise and fall of a reindeer herd. Scient. Month., **73**: 356–362.

SCOTT, R. F., E. F. CHATELAINE, and W. A. ELKINS. 1950. The status of the Dall sheep and caribou in Alaska. Trans. N. Amer. Wildl. Conf., **15**: 612–625.

SEVERINGHAUS, C. W. 1947. Relationship of weather to winter mortality and population levels among deer in the Adirondack region of New York. Trans. N. Amer. Wildl. Conf., **12**: 212–223.

SPENCER, D. L. and E. F. CHATELAIN. 1953. Progress in the management of the moose of south central Alaska. Trans. N. Amer. Wildl. Conf., **18**: 539–552.

SPIKER, C. J. 1933. Some late winter and early spring observations on the white-tailed deer of the Adirondacks. Roosevelt Wild Life Bull., **6**: 327–385.

WILDHAGEN, A. 1952. Aktuelt om villreinen. Papers on Game Research, **8**: 50–57, Helsinki.

WILLIAMS, A. B. 1925. Game trails in British Columbia. Scribner's, N. Y.

———. 1935. Fish and game in British Columbia. Sun Directories, Vancouver.

WILLIAMS, J. P. 1952. Alaskan Adventure. Stackpole, Harrisburg.

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THE WILDLIFE SOCIETY — REPORT OF BALLOT AUDIT COMMITTEE

The Committee, consisting of Everett R. Doman, chairman; James B. Trefethen, and Stewart M. Brandborg met in November 1955 with Executive Secretary Daniel L. Leedy and audited the nomination ballots for Regional Representatives to the Society's seven Regions, and also the votes regarding the dues increase. It was determined from the audit that the two nominees receiving the most points within each Region were:

Region		*Region*	
1	Roger M. Latham and William R. DeGarmo	5	Wendell G. Swank and F. M. Baumgartner
2	C. Edward Carlson and E. B. Chamberlain	6	A. Starker Leopold and J. Burton Lauckhart
3	Bill T. Crawford and Robert S. Campbell	7	Ian McTaggart Cowan and Anton deVos
4	Lee E. Yeager and Ralph R. Hill		

A large majority of voting members favored the annual dues increase from $5.00 to $6.00, effective for 1956.

On February 6, 1956, the Ballot Audit Committee assisted by Executive Secretary Leedy counted and audited the ballots for 1956-57 officers, regional representatives, and also the ballots cast for and against the revisions in the by-laws. The results of this count and audit are as follows:

Office	*Candidates*	*Winner*
President	Durward L. Allen Charles A. Dambach	Durward L. Allen
Vice-President	John S. Gottschalk Louis Krumholz	John S. Gottschalk

Regional Representatives elected were:

Region 1	Roger M. Latham	Region 5	Wendell G. Swank
Region 2	E. B. Chamberlain	Region 6	A. Starker Leopold
Region 3	Bill T. Crawford	Region 7	Ian McTaggart Cowan
Region 4	Lee E. Yeager		

Ballots on revision of the by-laws showed: In favor 1,091 Opposed 40.

IDENTIFICATION OF COLORADO BIG GAME ANIMALS BY THE PRECIPITIN REACTION

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This paper presents a method, the precipitin test, which can be employed in the identification of meats or blood stains in cases where game law violation is suspected and additional information is needed as evidence in court. The precipitin test is based upon the fact that when a foreign protein enters the circulatory system of a living animal, the recipient builds antibody to this foreign protein. Blood serum from the animal thus immunized, in contact with the same protein in a test tube, forms a visible precipitate. This antiserum, therefore, may be used to identify the protein.

The early work concerning the development and use of the precipitin reaction has been reviewed by Landsteiner (1936), Sherwood (1951) and others. Uhlenhuth (1901) and almost simultaneously Wasserman and Schütze (1901) recognized the value of the precipitin test and used it forensically in the identification of human blood and blood stains. Nuttall and Dinkelspiel (1901) found that meat extracts, blister fluids, semen, lachrymal secretions, pleuritis fluids, and mixtures of bloods could also be identified.

For many years the results of the precipitin test have been accepted by the American courts in cases involving identification of human and meat animal bloods, tissues, blood stains, and secretions. Little is reported, however, on the use of the precipitin reaction for the identification of the meats and bloods of game animals in law enforcement. The first reported case was by Gay (1908) who was able to distinguish venison from veal. Clark (1914) used the test in California to differentiate venison from beef, mutton, and bear meat and reported a conviction in a game law violation based upon the results. Fenstermacher and Pomeroy (1938) used the precipitin test to identify stains thought to be beaver blood and Brohn and Karschgen (1950) reported a method of differentiating venison from the meat of sheep, goat, cow, and swine.

[1] This paper is a portion of a thesis presented by the senior author to the Graduate School of Colorado A. & M. College in partial fulfillment of requirements for the degree of Master of Science.

Methods and Materials

The investigation necessitated the preparation of specific antisera using blood serum as antigen for the following animals common to Colorado: mule deer, elk, antelope, Rocky Mountain bighorn, horse, cattle, domestic sheep, and the human. These antisera were later tested against the sera, blood stain extracts, and meat extracts of animals of the above species. Following the method recommended by Proom (1943), 15 White Leghorn cockerels were injected with five ml. (two and one-half ml. in each thigh muscle) of alum-precipitated blood serum prepared by diluting 25 ml. of normal serum with 80 ml. of distilled water and precipitating with 90 ml. of a 10 per cent solution of potassium alum. The pH was adjusted to 6.5 with 5 normal NaOH and the mixture centrifuged. The deposit was twice washed with 200 ml. of 1:10,000 'Merthiolate' (trade mark of Eli Lilly and Company for Thimerosal) saline solution, and the final deposit made up to 100 ml. volume with 1:10,000 'Merthiolate' saline.

After 14 days the chickens were fasted for 24 hours to prevent serum cloudiness and were bled on the fifteenth day. The bloods were collected into sterile flasks and were allowed to clot at room temperature (from two to three hours). The sera were removed from the clots to sterile test tubes and were then centrifuged to remove the remaining red blood cells. The clear antisera, preserved with 'Merthiolate', were stored at 4°C. in 10 ml. quantities. Each of the prepared immune sera was tested to ascertain its specificity and sensitivity to normal serum (antigen) from each animal species under investigation. Meat extracts and blood-stain extracts from each animal were also tested against the antisera.

To prepare meat extracts 30 gm. of each

sample was dried and placed into a flask containing 50 ml. of physiological saline. The flasks were refrigerated for 24 hours and the extracts were clarified by filtration before use.

Suspected blood stains on material such as cloth or rope were extracted with physiological saline for 24 hours at 4°C. For each square centimeter of stained material one ml. of saline was used and, wherever possible, an unstained portion of the material was extracted for a control. For dried blood powder one ml. of saline was used for each four or five mg. In every case extracts were filtered to produce a clear solution.

Each prepared antiserum was standardized for potency or titer against homologous antigen diluted from 1:16 to 1:16,384 by the method of doubling dilutions. The highest dilution of antigen which was precipitated by the antiserum was considered the titer of the antiserum.

The ring method adopted for performing the precipitin test was carried out by placing the antigen over a layer of antiserum in a suitable tube. By this "interfacial technique" a positive reaction is visible within 60 minutes as a white zone or plane at the junction of the two clear fluids. Figure 1 shows positive precipitate rings at interface of antiserum and antigen. The reactions were best read against a black background with reflected light. All reactions were read in 15, 30, and 60 minutes after the overlay and were read as being positive (+), negative (−), or incomplete (±). The tests were performed in 25 mm. lengths of glass tubing whose inside diameter was three mm. The antiserum for each test was placed into the depression of a porcelain spot plate and by touching the tube ends to the antiserum an adequate amount was drawn up into the tube by capillary action. The tubes were placed upright into molding clay on a wooden base. With a capillary pipette the dilutions of an antigen, starting with the highest, were carefully layered over the antiserum so as to form a sharp interface between antigen and antiserum. An antigen control (physiological saline over antiserum) was run with each test.

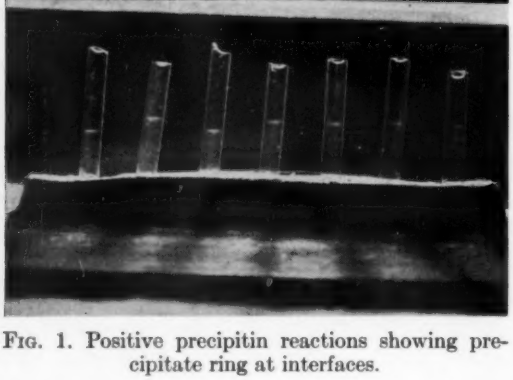

FIG. 1. Positive precipitin reactions showing precipitate ring at interfaces.

To test the effects of an adverse storage condition on the precipitin reaction, horse blood was dried on pieces of filter paper and stored in a metal container in front of a window. These papers were extracted and tested at two week intervals for eight months.

RESULTS

The domestic chicken proved to be a very satisfactory animal for the production of antisera against the animals used in this study. Single injections of five ml. of alum-precipitated antigens were adequate to stimulate high-titered antibody production in the chickens in 15 days. Variation in antibody response in duplicate birds were noted, however. Many of the antisera, when tested against homologous serum, showed precipitin titers of 1:16,384 or above and only a few had titers as low as 1:4,096. These titers were sufficiently high to overcome the difficulties of cross reactions with heterologous sera. Table 1 shows the cross reactions for the antisera which were selected for further work. It can be seen that in every case the homologous reactions occurred at much higher dilutions of the antigen than when heterologous antigens were used. Also the precipitates formed more rapidly and more intensely when the homologous antigens were tested. The heterologous cross reactions are probably due to the well-known genetic relationships of some of the animal species.

It has often been suggested that these partial reactions be removed by absorption of the antiserum with small amounts of heterologous antigens. In the course of this investigation numerous absorption techniques were tried but all failed to remove the heterologous reaction without lowering the titer of the serum.

In testing the antisera against meat ex-

TABLE 1.—HIGHEST SERUM ANTIGEN DILUTION PRECIPITATED BY EACH ANTISERUM IN 60 MINUTES

ANTISERA	ANTIGENS							
	Deer	Elk	Antelope	Bighorn	Horse	Cow	Sheep	Human
Deer #8764	16,384*	512	64	32	0	128	32	....
Deer #8799	16,384	64	16	32	0	64	16	....
Elk #1304	256	16,384	32	64	0	512	128	....
Antelope #1303	64	64	8,192	64	0	128	128	....
Antelope #1347	64	128	16,384	64	0	64	128	....
Bighorn #8776	16	32	64	8,192	0	32	128	....
Bighorn #8775	64	64	64	4,096	0	64	32	....
Horse #8784	0	0	16	16	16,384	32	32	....
Cow #8765	128	256	128	128	64	16,384	128	....
Cow #8762	32	64	32	32	0	16,384	64	....
Sheep #1317	32	32	32	128	0	32	8,192	....
Sheep #1319	64	128	64	64	0	128	8,192	....
Human #1320	0	0	0	16	0	0	0	4,096
Human #1321	0	0	0	0	0	0	0	4,096

* Figure represents highest dilution of antigen run. Actual titer may be higher.

tracts or blood-stain extracts, much lower titers were observed because the extraction process added an initial saline dilution factor. With meat extracts the precipitating titers were found to vary from 1:64 to 1:512 or higher, and the heterologous reactions from 1:1 to 1:32. In each case, however, the homologous reaction occurred at an antigen dilution at least eight times the heterologous dilution. No human tissue extract was used. With blood-stain extracts the homologous reactions varied from 1:32 to 1:512 or higher. In every case, as with the meat extracts, the reaction was at least eight times the heterologous reaction dilution. It is interesting that the anti-human blood serum showed no precipitation with any dilution of the stain extracts of the other species of wild or domestic animals (Table 1).

Bi-weekly testing of the horse-blood stains on filter paper stored by a window showed little decline in the ability of the precipitin test to identify the blood as that of the horse. A sample of elk meat, which had been in a home freezer for two and one-half years and was in very poor condition was extracted and tested. A very strong reaction with elk antiserum was obtained with this antigen in dilution of 1:32 while anti-deer serum gave a positive reading at 1:2 and anti-cow serum was positive with undiluted meat extract antigen.

Several tests on unknowns were made for the Colorado Game and Fish Department. These samples were collected by the wardens and brought to the laboratory for species identification. Some typical examples were the following:

Case #1: The suspected material consisted of a piece of dried blood found in the trunk of a car owned by a man suspected of shooting a deer illegally. Testing of serial dilutions of an extract of this dried blood against antiserum for each animal species produced highest precipitating titer with anti-deer serum. No controls were necessary in this test because the blood was dried without adhering to any foreign material. Further investigation brought a confession from the suspect.

Case #2: Tests made on suspected blood stains found on a cotton rope were positive for antelope. An unstained portion of the rope was extracted with saline for a control and produced no precipitation with antelope antiserum when used undiluted.

Case #3: Blood scraped from a trap was suspected by a game warden as being deer blood. The precipitin reaction indicated that the blood was that of an antelope. Additional investigation by the game wardens led to proof that the blood really was from an antelope and prevented a false accusation of the guilty hunter.

Case #4: A man suspected of killing a deer illegally was apprehended and blood stains were found on his clothing. These stains were alleged to be of chicken blood but the results of the precipitin test showed

the blood to be that of a deer. These results were accepted as evidence by the courts at a hearing in this case.

SUMMARY

An attempt to use the precipitin test for the differential identification of Colorado area big game and domestic animals (deer, elk, antelope, Rocky Mountain bighorn, horse, cow, domestic sheep, and human) proved quite successful. Antisera were prepared in the chicken using alum precipitated antigens. With high-titered specific antisera it was possible to accurately and quickly differentiate meat, blood, or blood stains. Although cross reactions did appear in the test, they did not interfere with accurate identifications because in no case did the heterologous reaction equal or exceed the homologous precipitin reaction in titer, speed, or intensity. Attempts to eliminate the cross reactions by absorption failed.

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LITERATURE CITED

BROHN, A. A. and L. J. KARSCHGEN. 1950. Precipitin test: a useful tool in game law enforcement. Trans. N. Amer. Wildl. Conf., **15**: 467–478.

CLARK, F. C. 1914. Forensic value of the precipitin test in the enforcement of game laws in California. U. of California, Publications in Path., **2**: 131–183.

FENSTERMACHER, R. and B. S. POMEROY. 1938. Identification of suspected beaver blood stains. Cornell Vet., **28**: 247–260.

GAY, F. P. 1908. A contribution to the forensic value of the musculo-precipitin test. Jour. Med. Res., **19**: 219–224.

LANDSTEINER, K. 1936. The specificity of serological reactions. Springfield, Illinois. Charles C. Thomas.

NUTTALL, G. H. F. and E. M. DINKELSPIEL. 1901. Experiments upon the specific test for blood. Brit. Med. Jour., **1**: 1141.

PROOM, H. 1943. Serological identification of animal species. Jour. Path. and Bact., **55**: 419–426.

SHERWOOD, N. P. 1941. Immunology. 3rd Ed. St. Louis. C. V. Mosby Co.

UHLENHUTH, P. 1901. Eine Methode für Unterschiedung der verschiedenen Blutarten, im Besondern zum differential diagnostischen Nachweise des Menschenblutes. Deutsche Med. Wochen., **27**: 82–83.

WASSERMANN, A. and A. SCHUTZE. 1901. Ueber eine neue forensische Methode für Unterscheidung von Menchen und Thierblut. Berlin. Klin. Wochen., **38**: 178–190.

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A PHEASANT NEST ACTIVITY RECORDING INSTRUMENT [1]

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Information on the exact time of the daily resting and feeding periods of incubating ring-necked pheasant (*Phasianus colchicus*) hens and the daily time of egg laying is rather meager. Leopold (1933) gave dawn and 4:00 p.m. as the times at which incubating pheasant hens leave the nest. Baskett (1947) found no definite time at which he could predict with accuracy that any individual hen would be away from the nest. He states that eggs were generally laid in the interval from about two hours after sunrise to two hours before sunset, or between the two daily feeding periods.

Difficulty in obtaining accurate data is largely responsible for this lack of information. Direct observation of the nest can be carried on only during daylight hours and may cause desertion of the nest or abnormal behavior by the hen. The need for a method of automatically recording the daily movements of nesting pheasant hens was evident.

A number of methods have been devised for recording nesting activities of song birds. Baldwin and Kendeigh (1927) described the use of a thermocouple and recording potentiometer to record nesting activities. The application of heat to the eggs registered the presence of the bird, and a drop in temperature depicted its departure. The thermograph could be placed in the nest with little difficulty, but the recording potentiometer required an electric current, a limiting factor in its use. Kendeigh and Baldwin (1930) detailed the use of an itograph, an electromagnetic device particularly adapted for use at nests with but one approach.

Another electromagnetic instrument, the terragraph, was invented by a German, Count von Hegendorf, for studying the habits of foxes and badgers, and was applied to bird activities by Bussman (1933). The apparatus consisted of a paper dial-plate marked at half-hour intervals on a revolving disk, with a carbon paper on top. A pencil attached to a telegraph magnet pressed on the carbon paper when the circuit was made, making a short line on the paper dial-plate below. Two small pieces of wood fastened at one end by a flat steel spring comprised the nest contact. The contact was placed in circuit by means of an insulated copper wire with two pocket batteries and the telegraph magnet.

Kuusisto (1941) used a glass tube containing mercury and with one end expanded like a thermometer as a thermo-contact. When the bird warmed the nest, the expansion of the mercury closed the circuit between two platinum points inserted in the tube. The contact was connected to an electromagnet with a pen writing on paper unrolled at a uniform rate. A different type of mercury contact was described by Marples and Gurr (1943). The weight of the bird on a contact similar to that of the terragraph caused a small wire projecting from the upper half to dip into a small cup of mercury on the lower half, thus closing the circuit.

Yates (1942) installed a photoelectric cell in such a way that the bird had to cut the beam on each trip to or from the nest, thus operating a relay connected to an electrically-actuated counter. Kendeigh (1952) suggested the possibilities such an apparatus might have if connected to a recorder rather than a counter. The reader is referred to Kendeigh (1952) for a more detailed discussion of work that has been done on song birds with automatic nest recording instruments.

Fant (1953) described an instrument for recording the movements of Hungarian

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partridge (*Perdix perdix*) hens during laying and incubation. He states, "it is essentially an electrical device powered by a car battery and consists of a simple make and break switch connected to a recording unit by a twin wire cable." The nest switch had two steel contacts, the upper arm extending to form a lever, which projected into the edge of the nest when placed in position. Depression of the lever by the hen caused the switch points to make contact, thus producing a closed circuit and recording on a smoked paper on a revolving kymograph drum.

Because the nest of the partridge more closely approximates that of the pheasant than does that of any other species for which automatic nest recorders have been used, Fant's instrument was adapted for use with nesting pheasant hens. The difficulties in using the device exactly as described under field conditions in Iowa's pheasant range soon became evident. As a result, certain modifications in equipment were made. The general principle of a switch in the nest connected to a pen recording on a rotating chart the movements of the nesting hen was retained.

THE NEST ACTIVITY RECORDER

An automatic "Tempscribe" temperature recorder (Bacharach Industrial Instrument Co., 7301 Penn Ave., Pittsburgh 8, Pa.) was modified for recording the daily movements of a nesting pheasant hen on the 24-hour rotating chart. The front part, or door, of the recorder was separated from the clock housing and the pen arm assembly removed. The bi-metallic coil was removed from its post with a hot, clean, soldering iron (this coil should be saved since the recorder can easily be reconverted into a temperature recorder). The pen arm was returned to its place, with care not to tighten the pivot screw too much. Several parts were then made and assembled according to the following directions.

1. Take one piece of 1/8" x 1/2" x 3 1/2" cold rolled steel and bend over steel block or in vise to make a coil holder. Drill 1/4" holes in middle of each end, the holes being laid out from the insides of the ends (Figure 1A).

2. From bakelite or fiber, turn a spool 1 3/4" long to fit lengthwise in the metal coil holder, 3/4" diameter at ends, and 1/4" diameter at center part where wire is to be wound. Drill 1/8", or slightly larger, hole all the way through spool (Figure 1B). Wind spool nearly full with #34 copper insulated wire, leaving the starting end of the wire out far enough to solder lead wires on when coil is completed. Wrap coil with scotch insulating tape, solder on lead wires, and wrap with more tape.

3. Take a 1/8" diameter, or slightly smaller, cold rolled steel rod about 2" long, and with jewelers hack saw cut slot 1/8" deep in end of rod (Figure 1C). This rod should slip freely through the coil form.

4. Bend a piece of .015 piano wire as shown in Figure 1D. Insert short bend into slot of rod and flatten in vise to hold the wire, thus making a drawbar to pull pen arm. Make a thin steel washer and press on rod up to the flattened end (Figure 1E).

5. Take a piece of 1/8" x 1/4" x 3/8" brass, or fiber, and cut a slot with hack saw blade lengthwise nearly through on 3/8" side (Figure 1F). Push this piece over tab bent up from front plate. This is to restrict the travel of the pen to make lines about 1/4" long on the chart.

6. Place wound coil in U-iron and insert 1/8" rod in coil hole. Hook piano wire drawbar into hole in pen arm. Place whole assembly on metal plate in such a manner as to allow plastic cover plate to fit over this assembly. Carefully remove plastic cover and scribe around metal U-iron. In center of the scribed area drill a 3/16" hole. Replace U-iron and scribe circle on back of U-iron through hole just drilled. Drill and tap for 10/32" screw in U-iron. This allows the magnetic coil to be swivelled to pull pen arm through a straight line.

7. A small .003 piano wire spring bent with hook on end (Figure 1G) is passed through slot in block that restricts travel of pen arm, along side of pivot shaft of pen arm, and hooks into same hole as the drawbar. This serves to return pen arm to outer position as the magnet pulls toward the center of the chart. The completed assembly is shown in Figure 1H.

The switch used at the nest is a microswitch with 12-ounce loading, normally open, with a flat spring bronze leaf screwed to the switch lever (Figure 1I). The bronze leaf is .050" thick, 3/8" wide, and 5" long. The addition of the leaf meant that much less

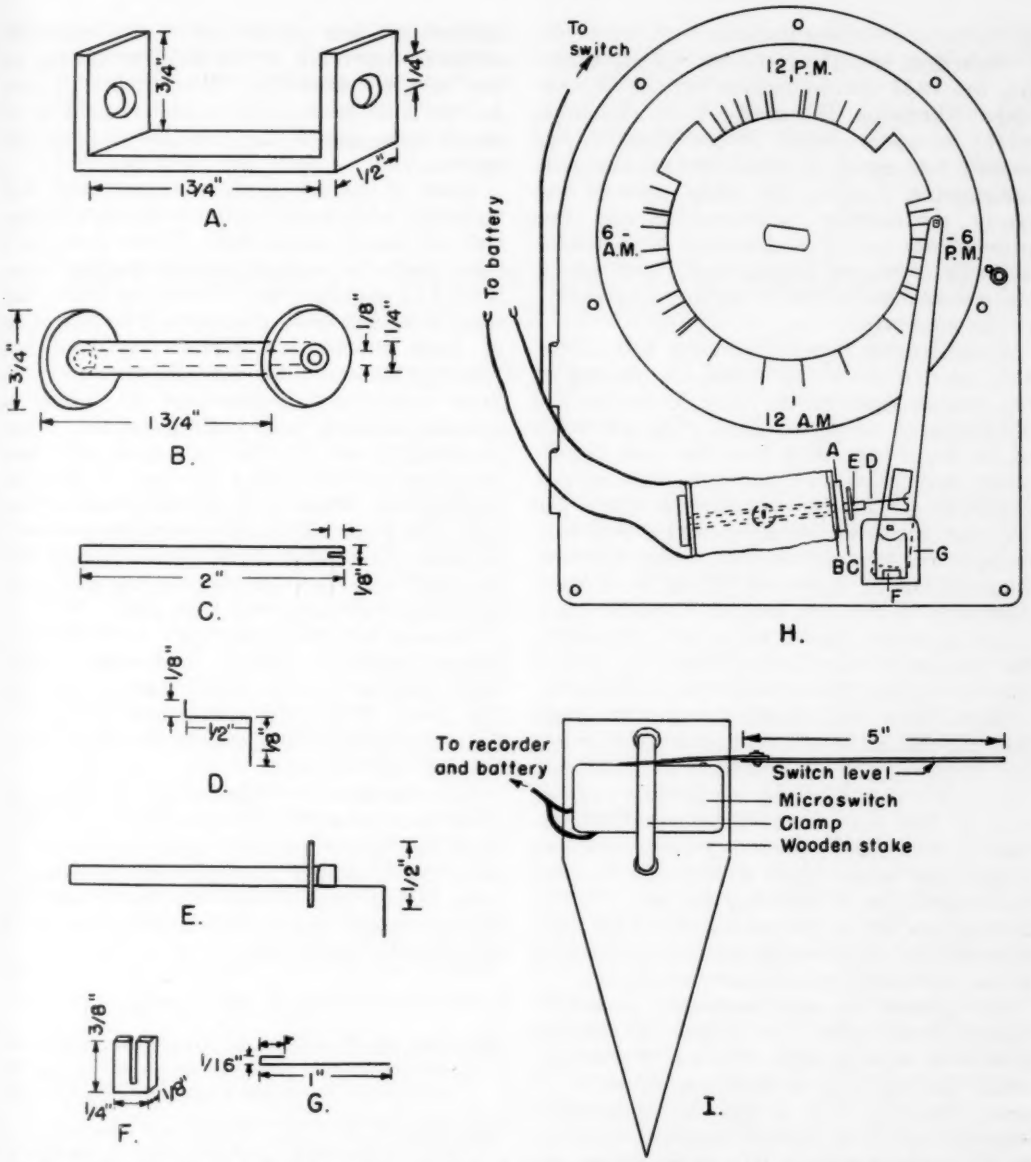

FIG. 1. Modification of a temperature recorder into an automatic nest activity recording instrument.

than 12 ounces was needed to depress the lever. The switch is mounted on a wooden stake and is covered to make it weather-proof. It is connected to a 6-volt, hot-shot battery with a 15-foot rubber-covered wire, the battery being connected to the magnetic coil in the recorder. The recorder and battery were placed in a weather-proof box about 15 feet from the nest.

When the hen was on the nest, the circuit was made (lever depressed by hen) and the magnet drew the pen arm to its inner radius. When the hen was absent from the nest, the switch was open and the pen recorded on its outer radius. While on the nest, any movement of the hen sufficient to open the circuit was shown on the chart as a line connecting the two radii. A simplified drawing of a typical chart is transposed on the door window in Figure 1H.

DISCUSSION

This nest activity recorder was used during the 1954 nesting season on the Winnebago Pheasant Research Area (Baskett, 1947) in north-central Iowa. Most of the season was spent in field testing the new instrument. During the early part of the study particularly, adjustments and improvements in the instrument were necessary. It is expected that continued use of the recorder will result in further perfections in the apparatus.

Considerable experimentation was necessary to determine the optimum placing of the switch lever in the nest to insure the obtaining of accurate data. The presence of the lever extending over the nest apparently did not bother the hens to any appreciable extent. In no instance where the recorder could be installed without having to flush the hen did the hen desert the nest when she later returned. When hens were flushed from the nest and the recorder then installed, some failed to return. However, the tendency of pheasant hens to desert their nests after being flushed is well known.

Data from nest activity recorders may provide biological information with practical significance. The importance of pheasant nesting losses in Iowa during the first cutting of hay has been demonstrated. Unfortunately, little can be done to prevent the loss of eggs and nests. Thus, a potential solution to the problem of reducing this great loss in production lies in decreasing the high rate of mortality to pheasant hens nesting in hay fields, enabling more of them to renest.

To achieve this end, hens must either be flushed from their nest before the mower arrives or mowing must be done, if possible, when the majority of hens are not on their nest. Flushing bars provide an incomplete answer, having decreased mortality from 35 to 75 per cent under various conditions on the study area. A knowledge of the daily periods when the majority of hens are off their nest might enable timing of hay mowing to occur primarily within these periods. Mowing during these intervals, coupled with the use of flushing bars, could result in an increase in pheasant production in a normal season.

By gathering data from several nests, the activity of pheasant hens when a farmer drives into his hay field and begins mowing could be determined. It is not known at present if a hen not on her nest at the time tends to move out of the field or returns to her nest to protect it. Similarly, it is not known if all hens on their nest remain on it or if some leave the nest as the mower approaches.

Most of the information secured with the recorder was from nests with incubation half or more completed. These hens left their nests for a single period ranging from 8 to 115 minutes and averaging about an hour in length each afternoon. The majority of these inattentive periods occurred between 3:00 and 6:00 p.m. However, these hens were very inconsistent in taking a morning resting and feeding period, often skipping it entirely. One hen took only two morning periods during the last 11 days of incubation. When a morning absence was taken by a pheasant hen, it usually occurred between 7:00 and 10:00 a.m. Nearly all recorded instances of egg laying occurred between 10:00 a.m. and 3:00 p.m.

During hatching the pen arm was in nearly constant motion, the chart paper being almost solidly inked during the last few hours. The total time required for the hatching process could be determined with the activity recorder.

Nine instances of predation on pheasant nests was recorded. Three occurred at night, thus ruling out crows, while the other six took place during daylight hours. Knowledge of the time of day the nests are destroyed might aid in determining the kind of predator responsible.

LITERATURE CITED

BALDWIN, S. P. and S. C. KENDEIGH. 1927. Attentiveness and inattentiveness in the nesting behavior of the house wren. Auk, **44**: 206–216.

BASKETT, T. S. 1947. Nesting and production of the ring-necked pheasant in north-central Iowa. Ecol. Monogr., **17**: 1–30.

BUSSMAN, J. 1933. Experiments with the terragraph on the activities of nesting birds. Bird Banding, **4**: 33–40.

FANT, R. J. 1953. A nest recording device. Jour. Ecol., **22**: 323–327.

KENDEIGH, S. C. 1952. Parental care and its evolution in birds. Illinois Biol. Monogr., **22**: 1–356.

KENDEIGH, S. C. and S. P. BALDWIN. 1930. The mechanical recording of the nesting activities of birds. Auk, **47**: 471–480.

KUUSISTO, P. 1941. Studien über die Ökologie und Tagesrhytmik von *Phylloscopus trochilus acredula* (L.). Acta Zoologica Fennica, **31**: 1–120.

LEOPOLD, A. 1933. Game Management. Charles Scribner's Sons, New York.

MARPLES, B. J. and L. GURR. 1943. A mechanism for recording automatically the nesting habits of birds. Emu, **43**: 67–71.

YATES, R. F. 1942. Counting the bird-house visits. Nature Magazine, **35**: 192.

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DIFFERENCES IN VULNERABILITY OF THE PREY OF NESTING KINGFISHERS [1]

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Most food-habit studies of the eastern belted kingfisher, *Megaceryle a. alcyon*, have been based on analyses of stomach contents or of individual regurgitated pellets. The present study consisted of qualitative and quantitative determinations of food organisms represented in the debris from two kingfisher nests excavated soon after their desertion by parent and young birds. The proportions of various food organisms in the nest remains were compared with the proportions of these organisms present in the stream on which the nests were located. Determinations of stream fauna were made by electric shocking, seining, and (for supplementary crayfish data) dip netting.

The kingfisher nests studied were located in a steep embankment on Fall Creek near the town of McLean, Tompkins County, in central New York. This embankment is composed largely of clay with occasional veins of silt. In this area Fall Creek has an average width of approximately 20 feet, and is characterized by swift, shallow water seldom over two feet deep, and a bottom of coarse rubble.

In that section of Fall Creek extending one-and-one-half miles above and below the kingfisher nest site (subsequently termed the study area), the following species of fish are known to occur (Anderson, MS; Eipper, 1953): *Salvelinus fontinalis*, Brook trout; *Salmo trutta*, Brown trout; *Catostomus commersoni*, White sucker; *Hypentelium nigricans*, Hog sucker; *Exoglossum maxillingua*, Cutlips; *Semotilus corporalis*, Fallfish; *Semotilus atromaculatus*, Creek chub; *Notropis cornutus*, Common shiner; *Rhinichthys atratulus*, Blacknose dace; *Rhinichthys cataractae*, Longnose dace; *Campostoma anomalum*, Stoneroller; *Micropterus dolomieui*, Smallmouth bass; *Micropterus salmoides*, Largemouth bass; and *Etheostoma nigrum*, Johnny darter.

Crayfishes in the study area are as follows (Crocker, 1952): *Orconectes p. propinquus*, *Cambarus b. bartoni*, *Cambarus robustus*.

The first kingfisher nest examined was occupied in the spring of 1950 and was opened in June of that year. In 1951 a second burrow was made within 100 feet of its predecessor and was opened when deserted by the birds in late June. From periodic inspections of the nest site in both years before and during construction and occupancy of the burrows, it was determined that both tunnels were constructed where no hole existed prior to commencement of dig-

[1] From a report submitted in partial fulfillment of minor requirements for the degree of Doctor of Philosophy at Cornell University.

[2] I am grateful for the assistance rendered by a number of the faculty and students of Cornell University in obtaining and interpreting the data presented here. Special thanks are due Dr. Oliver H. Hewitt for his guidance and help in all phases of the study, and to Dr. Edward C. Raney who assisted in identification of fish bones and furnished information on breeding habits of local minnows. Messrs. Paul Neth, Jack Miller, Max Carpenter, and Robert Touhey assisted in the 1951 electrical inventory and in sorting nest remains. Dr. Denton W. Crocker, Colby College, sorted and identified crayfish from nest remains and the electrical inventory, furnished data from his personal collections of crayfish from the study area, and contributed much to the interpretation of the crayfish data.

ging by the parent birds. It seems reasonable to conclude that in each year the food remains collected represented debris accumulated by a single kingfisher family.

METHODS

NEST MATERIAL. Identical procedures were followed in obtaining and processing food remains in the 1950 and 1951 kingfisher nests. The nests were similar in shape and dimensions and each nest was carefully excavated from above, revealing a tunnel approximately three inches high by four inches wide in cross section which extended into the bank a distance of 12 inches. Beyond this point, the tunnel was expanded into a burrow eight inches high, 11 inches wide, and 23 inches long. The inner 15 inches of the burrow was tightly packed with a uniform mixture of silt, excrement, and the remains of fishes and crayfishes.

All debris was removed from the burrow and gently washed in a receptacle of wire mesh having 18 squares to the inch. This process served to remove virtually all soil and excrement without loss of the structures used in enumerating food organisms. After cleaning and drying, all nest material was carefully sorted. Of the fish bones present in the nest remains, those saved for identification and enumeration were cleithra, preopercles, pharyngeals, dentaries, and maxillaries. In the crayfish remains, copulatory stylets, seminal receptacles, rostra, chelae, and mandibles were retained. Remains of no animals other than fish or crayfish were found in either nest.

Fish bones in the nest material were identified by comparison with corresponding bones in a collection of specimens of known identity representing all species found in Fall Creek within three miles of the nest site. It was frequently impossible to distinguish with certainty between bones from fish of the genera *Notropis* and *Semotilus* in the nest remains, and enumerations of these two groups (representing three species) were therefore combined in the tabulations of results. For the same reasons, counts of *Rhinichthys* represent combined data for two species, and numbers of brook trout and brown trout were similarly grouped. Since all fish bones employed in this analysis occur in pairs in the living animal, each was enumerated as 'left' or 'right.' The maximum number of a given fish species or group was determined from the count of the bone (left or right) most abundant in the remains of the fish in question.

The methods employed in identifying and enumerating crayfish remains in the nest material were similar in all respects to those described above for fish bones. Because crayfish remains in the nest debris had become distorted by drying and shrinking, they could be accurately identified only to genus.

STREAM FAUNA. In July, 1951, three weeks after excavation of the second kingfisher nest, a sample of stream fauna was obtained by electric shocking of an 800-foot section of Fall Creek directly adjacent to the nest site. The shocker employed consisted of a 230-volt, 2,500-watt AC generator connected to six metal grounding rods driven into the stream bank along the water line and to a floating electrode of half-inch copper shielding cable extended from bank to bank. As the floating electrode was moved slowly upstream, all stunned fish and crayfish were collected with dip nets for subsequent enumeration by species. Water depths in this section of stream were less than two feet except in a single pool having a maximum depth of four feet.

Supplementary data are available from Anderson (MS), who in the spring of 1949 made a collection of 155 fish in Fall Creek at a point one-and-one-half miles below the nest site using a 10-foot minnow seine. All fishes obtained in that collection were enumerated by species.

Additional information on crayfish in the study area was obtained by Crocker (personal communication) who, in June, 1950, made four collections of crayfish by dip net from an area of Fall Creek approximately one-half mile below the kingfisher nest site. Data from these collections were subsequently made available for the present study.

RESULTS

Total numbers and percentages of fish and crayfish in the kingfisher nest remains are presented in Table 1. Proportions of the two food classes were virtually identical in the nests of both years. No meaningful comparison can be drawn between these data and those obtained in the electrical inventory because under the conditions of this study crayfish were less vulnerable to cap-

TABLE 1.—OCCURRENCE OF FISH AND CRAYFISH IN THE REMAINS FROM TWO KINGFISHER NESTS

Food Class	Number and (per cent)	
	1950 nest	1951 nest
Fish	164 (50.5)	234 (50.6)
Crayfish	161 (49.5)	228 (49.4)
Total	325 (100.0)	462 (100.0)

ture by electric shocker than were the fish. Hence, the shocker collection presumably gave a biased estimate of the proportion of total fish to total crayfish in the study section.

FISH—Occurrence of the various species or groups of fish in the nest remains and in the two stream samples is given in Table 2. It is apparent that there is fair agreement between percentages of any given food item or group in the two nests.

In comparing the two stream samples of fish, the relative abundance of major groups (families) is roughly similar in both collections, except in the case of Catostomidae. Within these major classifications, however, there are marked discrepancies in occurrence between the two samples, as in the case of blacknose and longnose dace, and in the category embracing the common shiner, fallfish, and creek chub. These discrepancies may be attributed in part to differences between collecting sites and dates and between methods used to obtain the two stream samples, in addition to the variation to be expected between any two samples from a single population.

Combined data on occurrence of fishes in the two kingfisher nests and in the two stream samples (Table 2, columns 4 and 7) are compared graphically in the upper portion of Figure 1. The accuracy with which the data on stream fauna represent the actual proportions of fishes in the kingfishers' foraging area is subject to question because of the sampling limitations mentioned in the preceding paragraph, coupled with the small number of stream samples obtained. Consequently most of the differences between the occurrence of fish in the

TABLE 2.—COMPARISON OF THE OCCURRENCE OF FISHES IN THE REMAINS FROM TWO KINGFISHER NESTS AND IN TWO STREAM SAMPLES

Fish	Number and (per cent)					
	Nest remains			Stream samples		
	1950	1951	Combined	Seining (Spring, 1949)	Electrical inventory (July, 1951)	Combined
Salmonidae (Brook and/or brown trout[1])	7 (4.3)	23 (9.8)	30 (7.5)	0 (0.0)	1 (0.2)	1 (0.2)
Catostomidae	20 (12.2)	24 (10.3)	44 (11.1)	19 (12.3)	10 (2.1)	29 (4.6)
White sucker	6 (3.7)	11 (4.7)	17 (4.3)	5 (3.2)	2 (0.4)	7 (1.1)
Hog sucker	14 (8.5)	13 (5.6)	27 (6.8)	14 (9.0)	8 (1.7)	22 (3.5)
Cyprinidae	134 (81.7)	172 (73.5)	306 (76.9)	133 (85.8)	462 (97.7)	595 (94.7)
Blacknose and/or longnose dace[1]	4 (2.4)	21 (9.0)	25 (6.3)	42 (27.1)	443 (93.7)	485 (77.2)
Stoneroller	107 (65.3)	107 (45.7)	214 (53.8)	17 (11.0)	17 (3.6)	34 (5.4)
Common shiner, fallfish, and creek chub[1]	23 (14.0)	44 (18.8)	67 (16.8)	74 (47.7)	2 (0.4)	76 (12.1)
Ameiuridae (Brown bullhead)	3 (1.8)	15 (6.4)	18 (4.5)	0 (0.0)	0 (0.0)	0 (0.0)
Percidae (Johnny darter)	0 (0.0)	0 (0.0)	0 (0.0)	3 (1.9)	0 (0.0)	3 (0.5)

[1] Finer distinctions not possible in the nest material.

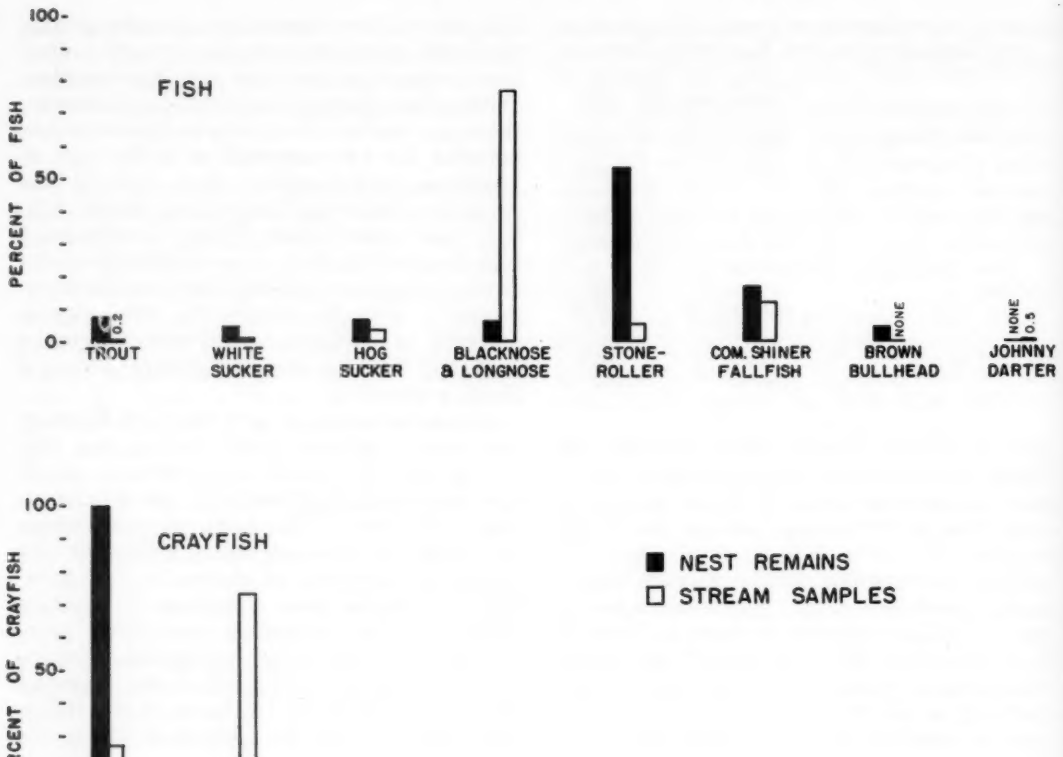

FIG. 1. Percentages of food organisms present in kingfisher nest remains and in samples from the adjacent stream (combined data for two nests and two stream samples).

nest remains and in the stream samples are of questionable significance, and statistical tests of these differences are unwarranted.[3] Despite these limitations, the discrepancies between nest remains and stream fauna with regard to relative abundance of stonerollers and of blacknose plus longnose dace appear too great to be reasonably attributed to sampling error alone. Anderson (MS), who recorded the number of each species collected at 39 stations along Fall Creek and its tributaries, stated that the stoneroller (the dominant fish in both years' nest remains), although distributed throughout the Fall Creek drainage, never occurs in large numbers or as a dominant form, although it is possible that Anderson's seining consistently failed to sample this bottom-dwelling species adequately.

CRAYFISH—Numbers and percentages of the two crayfish genera represented in nest remains and in two stream collections are given in Table 3. A graphic comparison of the combined data for nests and for stream samples appears in the lower portion of Figure 1. Although five different structures were available for generic identification of crayfish remains in the nest debris, *Orconectes*, sp., which made up more than two-thirds of the crayfish in both stream samples, was entirely absent from both nests. To the writer's knowledge, these were no morphological or behavioral differences between the two genera which could have biased the stream samples in favor of *Orconectes* in this study.

[3] Brown bullheads, *Ameiurus nebulosus*, present in small numbers in both years' kingfisher nest remains, were presumably captured in a small pond containing this species located approximately one mile below the nest site and adjacent to Fall Creek.

TABLE 3.—COMPARISON OF THE OCCURRENCE OF CRAYFISH IN THE REMAINS FROM TWO KINGFISHER NESTS AND IN TWO STREAM SAMPLES

Crayfish	Number and (per cent)					
	Nest remains			Stream samples		
	1950	1951	Combined	Dip net (June, 1950)	Electrical inventory (July, 1951)	Combined
Cambarus spp.	161 (100.0)	228 (100.0)	389 (100.0)	30 (32.2)	21 (21.6)	51 (26.8)
Orconectes sp.	0 (0.0)	0 (0.0)	0 (0.0)	63 (67.7)	76 (78.4)	139 (73.2)

DISCUSSION

PRESENCE OF FOOD REMAINS IN THE NEST—Accumulations of food remains in kingfisher nests similar to those encountered in the present study have been reported by Bailey (1900), Nichols (1915), and others. Studies of kingfisher food habits by Salyer and Lagler (1949) indicate that nesting adult birds remove their own pellets of undigested food remains from the nest at frequent intervals during the day. White (1939) found that all fish bones, regardless of size, were digested by kingfisher nestlings during the first month of life, while Bent (1940) states that ". . . the young remain in the nest for about 4 weeks or more. . . ." From the foregoing account it would appear that during most of the time when the nest is occupied there are no appreciable amounts of food remains being deposited in the burrow by either nestlings or parents, and that the remains of 325 and 462 food organisms obtained from the 1950 and 1951 nests, respectively, represent chiefly the pellets regurgitated by older nestlings after cessation of bone digestion. That such quantities of food could have been ingested by a family of kingfishers in so short a period of time appears plausible in the light of White's (1936) estimate that a brood of seven kingfisher nestlings require at least 150 fish per day.

DIFFERENTIAL VULNERABILITY OF FOOD ORGANISMS—If it is assumed that the outstanding discrepancies between percentages of food organisms in the kingfisher nest remains and in the stream samples are greater than could be logically accounted for by chance variation in sampling of the stream fauna, it would seem that these discrepancies must be attributed either to selectivity by the parent birds, or to differences among the prey species in their vulnerability to kingfisher predation.

Concerning fishes in the nest remains, it would appear that longnose and blacknose dace were much less and stonerollers much more subject to kingfisher attack than would be expected on the basis of their relative abundance in the stream fauna. It is possible that the dace, being the smallest of the forage species present in the study area, were not as readily detected by kingfishers as were the larger fishes. In addition, there is a distinct possibility that dace were actually avoided by the parent birds in favor of larger fish. White (1938, 1953) found that the size of fish fed to kingfisher nestlings increased with the size of the growing birds. If a similar behavior pattern was manifest by the birds involved in the present study, the nest material, which was presumably dominated by the food remains of advanced nestlings, would reflect a selective predation on the part of the parent birds in favor of larger fish, and would tend to exclude the smallest fish, in this instance the dace.

The most plausible explanation for the predominance of stonerollers in the nest remains is that, in addition to the particularly suitable size of the adults as food for large nestlings (White, 1953), certain behavior patterns associated with reproduction of the stoneroller render it especially vulnerable to kingfisher attack. Although the spawning time of all minnows represented

in the stream samples appears to coincide in Fall Creek with the period when older nestlings were present in the kingfisher burrows, nest-building activities of the stoneroller are distinguished by large concentrations of adults in shallow water (Raney, 1940). Furthermore, after completion of spawning, many dying, blinded, or otherwise injured and weakened male stonerollers are commonly observed (E. C. Raney, personal communication).

The striking discrepancy between percentages of the two crayfish genera in nest remains and in stream samples appears to be largely attributable to behavior differences associated with reproduction. Although both genera breed during autumn months, in Fall Creek only *Cambarus* is known to breed in the spring as well (Crocker, 1952). The functional Form I copulatory stylets of adult male *Cambarus* and *Orconectes* in breeding years differ morphologically from the non-functional Form II stylets characterizing the alternate non-breeding years. Thus it was possible to determine the proportion of breeding and non-breeding male *Cambarus* represented by stylets in the nest remains for comparison with corresponding percentages present at the same season in the adjacent stream. This comparison is presented in Table 4, where it is seen that in both years of the study breeding males were dominant in the nest remains when non-breeding males predominated in the stream. These data, although confined to males (which outnumbered females by approximately three to one in both nests), suggest that breeding crayfish were far more vulnerable to predation than were the non-breeders. It seems likely that the courtship or mating behavior of crayfish might render them more conspicuous to kingfishers. Since apparently *Cambarus* is the only spring breeder in Fall Creek, selection of breeding crayfish would result in the selection of *Cambarus* over *Orconectes* as was manifest in the nest remains. The foregoing hypothesis, however, fails to explain why *Cambarus* alone was represented in the remains of non-breeding male crayfish in the kingfisher nests. The available data suggest that breeding behavior was not the only characteristic of *Cambarus* which rendered it more vulnerable than *Orconectes* to kingfisher predation.

SUMMARY

1. Two kingfisher nests located on Fall Creek, in central New York, were excavated soon after their desertion by parent birds and young in June 1950 and in June 1951. Percentages of food organisms in the nests were determined from counts of identifiable bones in the nest debris. No remains of animals other than fish or crayfish were found in either nest.

2. Data on the stream occurrence of fish and crayfish were obtained by electrical inventory of an 800-foot section of Fall Creek directly adjacent to the nest site. Supplementary information on the occurrence of fishes in the study area was obtained by seining, while additional samples of cray-

TABLE 4.—PERCENTAGES OF FUNCTIONAL AND NON-FUNCTIONAL COPULATORY STYLETS OF MALE *Cambarus* IN THE REMAINS FROM TWO KINGFISHER NESTS AND IN STREAM SAMPLES

Type of stylet	Per cent of stylets					
	Nest remains			Stream samples		
	1950	1951	Combined	Dip net (June, 1950)	Electrical inventory (July, 1951)	Combined
Functional (Form I).....	88	85	86	7	0	4
Non-functional (Form II or immature)[1].....	12	15	14	93	100	96
Total number of stylets.....	99	172	271	30	26	56

[1] Distinctions between immature and Form II stylets not possible in the nest material.

fishes in the study area were taken by dip net.

3. Remains of 325 and 462 forage organisms were obtained from the 1950 and 1951 nests, respectively. In the light of previous studies, it seems probable that these accumulations represent chiefly the pellets regurgitated by older nestlings after cessation of bone digestion.

4. In debris from both nests, total food organisms were almost equally divided between fish and crayfish.

5. There was fairly close agreement between percentages of any given species or group of fish in the two nests. However, there were considerable discrepancies in percentage of a given fish species or group between the two stream samples.

6. Comparisons between the occurrence of fishes in the kingfisher nest remains and their occurrence in the stream fauna were limited by the inadequacy of stream samples. Nevertheless, the scarcity of blacknose and longnose dace and the abundance of stoneroller minnows in the nest remains were so pronounced, in comparison to the occurrence of these forms in either stream sample, that the possibility of ascribing these differences solely to inadequate stream sampling appears remote. In the light of previous studies it seems possible that the dace, smallest of the species present in the study area, were actually avoided by the foraging parent birds in favor of larger fish. The most plausible explanation for the preponderance of stonerollers in the kingfisher nest remains is that, in addition to their particularly suitable size as food for large nestlings, behavior associated with spawning greatly increased the vulnerability of this species during the period when advanced nestlings were present in the kingfisher burrow.

7. Although more than two-thirds of the crayfish taken in both stream samples belonged to the genus *Orconectes* and one-third to *Cambarus*, debris from both kingfisher nests contained only *Cambarus* remains. Of the two genera, only *Cambarus* is known to breed in the spring in Fall Creek. Although the stream population of male *Cambarus* was comprised largely of non-breeders, breeding males predominated in the nest remains. Therefore it seems likely that breeding behavior of *Cambarus* made members of this genus more vulnerable to kingfisher attack than was *Orconectes*. Since all of the non-breeding crayfish males present in the nest remains of both years were also of the genus *Cambarus*, it appears that reproductive behavior was not the only characteristic of *Cambarus* which rendered it more vulnerable than *Orconectes* to kingfisher predation.

LITERATURE CITED

ANDERSON, P. K. MS:1949. A preliminary survey of fish distribution in the streams of the Fall Creek drainage system in central New York. On file, Department of Conservation, Cornell University.

BAILEY, W. L. 1900. The kingfisher's home life. Bird-Lore, **2**: 76–80.

BENT, A. C. 1940. Life histories of North American cuckoos, goatsuckers, hummingbirds and their allies. Bull. U. S. Nat. Mus., No. 176. viii+ 506 pp.

CROCKER, D. W. 1952. Studies of the distribution, life histories, and taxonomy of the crayfishes of New York State. Ph.D. Thesis, Cornell University Library.

EIPPER, A. W. 1953. The effect of hatchery growth rate on the survival of brown trout planted in Fall Creek, New York. Ph.D. Thesis, Cornell University Library.

NICHOLS, J. T. 1915. On fish bones in a kingfisher's nest. Copeia, **21**: 27–28.

RANEY, E. C. 1940. Nests under the water. Bull. N. Y. Zool. Soc., **43**(4): 127–135.

SALYER, J. C. and K. F. LAGLER. 1949. The eastern belted kingfisher, *Megaceryle alcyon alcyon* (Linnaeus), in relation to fish management. Trans. Amer. Fish. Soc., **76**: 97–117.

WHITE, H. C. 1936. The food of kingfishers and mergansers on the Margaree River, Nova Scotia. Jour. Biol. Bd. Can., **2**(3): 299–309.

———. 1938. The feeding of kingfishers; food of nestlings and effect of water height. Jour. Fish. Res. Bd. Can., **4**(1): 48–52.

———. 1939. Change in gastric digestion of kingfishers with development. Amer. Nat., **73**(745): 188–190.

———. 1953. The eastern belted kingfisher in the maritime provinces. Bull. Fish. Res. Bd. Can., No. 97. 44 pp.

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A REPORT ON THE BEAVER DIE-OFF IN MICHIGAN [1]

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With the opening of the 1953 beaver trapping season in Michigan, Conservation Department field personnel began receiving reports of dead beaver. From the number of reports it was evident that an epizootic had occurred among these animals in the western counties of the Upper Peninsula. Trappers found carcasses floating in flowages and along stream margins, and in several instances sick and weakened beavers were found on land short distances from water. Approximately 180 dead or sick beavers were reported during the trapping season. The greatest concentration of carcasses occurred on the headwaters of the East Branch Presque Isle River in Gogebic County. Obviously, these scattered, voluntary reports received by the Game Division represent only a small fraction of the total number of animals that must have died. Conditions that prevailed in flowages not readily accessible to trappers were, of course, not known. Also, as subsequent field observations have shown, the activities of scavengers quickly scatter and destroy the remains of dead beavers. Concurrent with this situation in the Upper Peninsula, trappers in adjoining counties in northern Wisconsin were reporting a die-off of beavers (Knudsen, 1953).

Gross pathological examinations of carcasses by L. D. Fay in some instances disclosed lesions characteristic of tularemia, whereas in many carcasses there was no obvious diseased condition. Attempts to isolate *Pasteurella tularensis* from carcasses, or from water and mud collected from flowages where die-off had occurred, were unsuccessful. Laboratory animals were taken into the field and inoculated with freshly-collected water to insure infection. *Post mortem* materials from three fresh carcasses were sent to Dr. William Jellison, U. S. Public Health Service Laboratory, Hamilton, Montana, for examination. He, too, was unable to demonstrate tularemia. However, during the trapping season three serologically-confirmed cases of this disease occurred among Michigan trappers in the Upper Peninsula. There were several other suspected human cases but blood samples for serological confirmation were not taken. In all three diagnosed cases, the trappers had found and skinned either dead or sick beavers. Thus this evidence, in spite of the negative bacteriological findings, was highly suggestive that tularemia was responsible, at least in part, for beaver mortality.

Field studies made during the summer of 1953 by the authors showed that die-off was still in progress. It appeared that muskrats were also being affected as carcasses of these animals were found in a flowage where beavers had died. However, the rapid decomposition of carcasses during warm weather, which made it nearly impossible to collect material suitable for bacteriological examination, together with the prompt consumption of them by scavengers, especially bears, made it difficult to determine

[1] Paper #3 Tularemia Project, School of Natural Resources; in cooperation with the Department of Bacteriology and School of Public Health, University of Michigan, and the Michigan Department of Conservation; supported by Research Grant E688, National Institutes of Health and Faculty Research Grant #914, Horace H. Rackham School of Graduate Studies, University of Michigan. This paper has been revised since its acceptance for publication to include 1955 observations.

the progress of the epizootic. Serological examinations of blood from beavers live-trapped from surviving colonies in die-off areas failed to disclose the presence of tularemia antibodies.

Prior to the beaver trapping season in 1954, plans were made with the Conservation Department for the prompt collection of any fresh beaver carcasses that might be found. Mortality did occur but it did not assume the proportions of the previous year. Approximately 35 dead beavers were reported from the Upper Peninsula. In Gogebic County, where 50 carcasses had been found during April, 1953, only one was reported for 1954. During both years, beaver die-off was restricted largely to the western portion of the peninsula, although several dead beavers were found in Alger and Schoolcraft Counties.

In addition to those beaver carcasses reported from the Upper Peninsula in 1954, one dead beaver was found in Gladwin County in the central portion of the Lower Peninsula. Examination of this specimen by the writers disclosed lesions suggestive of tularemia. Also one carcass found near Wakefield in Gogebic County showed similar symptoms. Patholgenic agents which proved to be lethal to white mice were isolated from both carcasses. After the virulence of the agents was well established through repeated passages in laboratory animals, infected materials were turned over to Dr. W. J. Nungester and Mr. Frank Zago of the Bacteriology Department, University of Michigan, for study. *Pasteurella tularensis* was isolated in both instances. From the earlier unpublished observations of S. C. Whitlock and the work of Green and Shillinger (1934) this disease was known to occur in Michigan in muskrats, cottontails, and snowshoe hares and *P. tularensis* was isolated from tick pools from ruffed grouse. This paper reports the first records of tularemia in the beaver for the state.

By 1955 the epizootic appeared to have run its course. Only seventeen beavers were reported by trappers. There was no evidence that abnormally high mortality continued to occur during that summer. One carcass was obtained for bacteriological studies, but putrefication was in an advanced stage and attempts to isolate *P. tularensis* were unsuccessful.

From the distribution of dead beavers during the three-year period, 1953 through 1955, it is evident that the epizootic spread eastward across the Upper Peninsula (Fig. 1). During the first year beaver die-off occurred primarily in the west end, with the greatest number of carcasses reported from Gogebic County. In the second year mortality was less and still confined chiefly to the western counties. However, the greatest number of carcasses was reported from Iron County, east of Gogebic County. Also there was an increase in the number of reports

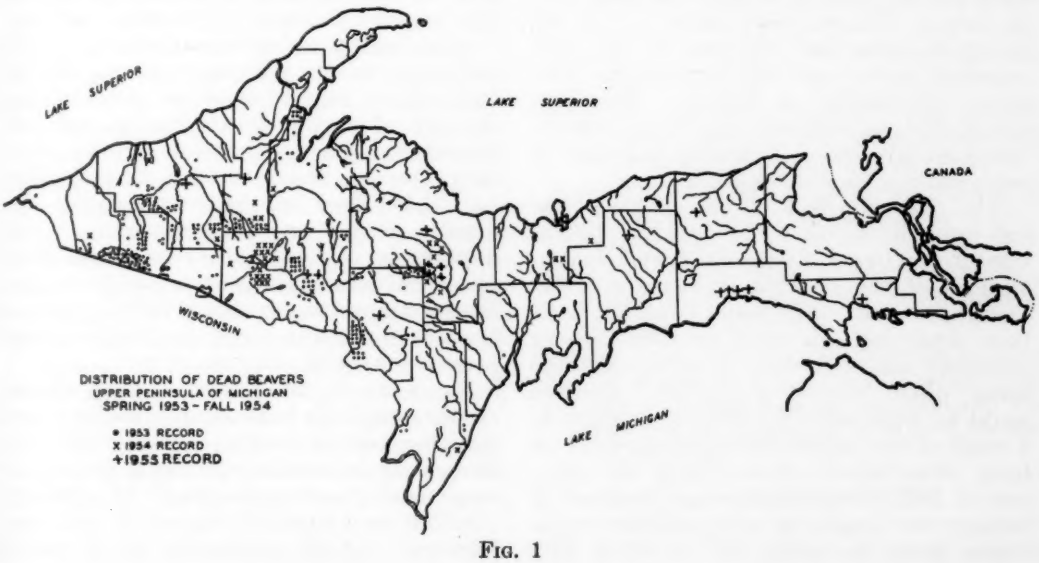

FIG. 1

from the central portion of the peninsula over the previous years. In 1955, the 17 dead beavers found were chiefly from scattered locations in the central and eastern counties. No carcasses were reported from Gogebic County where initial losses had been highest. This eastward spread of the epizootic across upper Michigan follows the regional pattern of beaver mortality in the upper lake states and central Canada. An epizootic among these animals occurred during 1948 to 1951 in Manitoba and northern Ontario (Labzoffsky and Sprent, 1952) then appeared to spread across northern Minnesota (Stenlund 1953) and Wisconsin (Knudsen 1953), finally reaching the Upper Peninsula of Michigan in 1953.

An attempt was made to determine whether or not the epizootic in Michigan was associated with a specific set of environmental conditions. The results were not conclusive. Beaver colonies along certain streams were entirely wiped out while colonies on other streams were unaffected. In one instance, a colony of two or three animals was destroyed while other colonies on the same stream located above and below it were unaffected. However, it appeared that most of the beaver mortality had occurred on watersheds where light sandy soils predominated. The forest cover on such soils is frequently aspen, a preferred food of beavers. On the streams where aspen was abundant and readily available to beavers, local concentrations of these animals had developed. Consequently many of the affected flowages had histories of long and repeated beaver use and, as a result, were frequently marshy in character. However, die-off was not restricted entirely to beavers living on streams as mortality occurred in some colonies located on lakes.

The over-all effect of the epizootic has not been disastrous to the beaver population of the Upper Peninsula. Local concentrations of the beavers in Gogebic, Iron, Dickerson and Ontonagon counties have been destroyed. In other counties beaver mortality was scattered. In many of these areas where mortality occurred declines could be expected even without disease, as a result of the rapidly diminishing supply of food. Observations made during the summer of 1954 showed that small numbers of beavers were beginning to repopulate streams where heavy mortality had occurred. The epizootic served the purpose of reducing the beaver population so that it was more nearly in balance with the carrying capacity of the streams.

Pasteurella tularensis was first isolated from beavers in 1938 during a die-off of these animals in Wyoming (Hammersland and Joneschild, 1940; Scott, 1940). Since then outbreaks of the disease occurred in several western states and the central provinces of Canada prior to the widespread epizootic in the upper lake states. Beaver die-offs are not a recent phenomenon; there are accounts of such happenings in the journals and published narratives of early fur traders (Tanner, 1830; Coues, 1897; Ferris, 1940). Upon opening carcasses the only abnormal condition reported by the early trappers was a bloody congestion about the heart. The cause of these early die-offs will, of course, never be known, but in light of recent events tularemia may logically be suspected.

The epidemiology of epizootic tularemia in beavers is still largely a matter for speculation. Certainly high populations of these animals must be one factor in the occurrence and spread of the disease. Whether waterborne tularemia, a condition frequently associated with an epizootic but not demonstrated in Michigan, is the cause or an effect of the epizootic is not yet known. Jellison *et al.* (1942), in a discussion of an outbreak of tularemia among beavers in Montana, was of the opinion that this disease in beavers may occur in conjunction with epizootics among terrestrial animals living in proximity to the affected flowages. He felt that water might serve as the medium through which the disease was transmitted. Beavers are generally considered to be singularly free of blood sucking ectoparasites, *i.e.*, ticks, fleas, mites, and sucking lice, usually found on most mammals. This hypothesis of water contamination from terrestrial animals was proposed to explain the spontaneous occurrence of tularemia in beavers in the absence of a suitable arthropod vector for the disease.

We have found a tick, *Ixodes banksi*, parasitizing both beavers and muskrats and infesting beaver lodges. Initially this was thought to be a rediscovery of a species not seen since it was described by Bishopp (1911) from a muskrat trapped in Arkansas. However, several specimens of *I. banksi*

from Ontario beavers have recently come to light. These specimens, collected in 1949 and 1950, had been confused with *Ixodes cookei*, a similar-appearing tick which is commonly found on the woodchuck (Kohls, personal communication). Judd (1954) reported *I. cookei* from a beaver trapped in the Sudbury District, Ontario. Lawrence examined this specimen and found it to be *I. banksi*.

The distribution of *I. banksi* in Michigan is restricted to the Upper Peninsula. Evidence from interviews with long-time resident trappers indicated that *I. banksi* may be a recent arrival on the scene. None of the trappers interviewed could recall finding "beaver ticks" prior to 1953 but several observed them that year. Our collection records suggest a recent invasion of this tick and indicate an eastward movement of it across the Upper Peninsula reaching the eastern end during 1955. In a sample of 68 live-trapped beavers, from Iron and Gogebic Counties, 18 or approximately 30 per cent were found parasitized by this tick. It is interesting to note that the first appearance of ticks on beavers closely followed the 1953 report of wide-spread mortality among these animals.

It has been our experience that the ticks usually attach deep in the external meatus of the ear and rarely along the outer margin of the pinna. However, we do have two reliable reports from trappers of instances where ticks were found attached to beavers at other places than on the ears, namely, the lips and a bare spot on the back. In both cases the parasites were removed and destroyed by the trappers so that identification was impossible.

In addition to checking the ears of beavers and muskrats, 107 beaver houses within the general area of the die-off were opened and the nest material examined for the presence of ixodid ticks. Berlese funnels were used in extracting the arthropods present in the nest material. Thirty-six lodges, approximately 34 per cent were found to be infested with *I. banksi*. Of these 36 lodges, three-fourths were vacant at the time they were examined, presumably as a result of the epizootic.

In Ontario *Ixodes banksi* has been found in two localities in the western part of the province in the general area where beaver mortality has occurred. Although this tick has not previously been incriminated as a vector of tularemia, other members of the genus *Ixodes* are proven vectors. The field evidence is certainly suggestive that *Ixodes banksi* may be involved in the transmission of tularemia and efforts are now being directed towards testing this hypothesis.

LITERATURE CITED

BISHOPP, F. C. 1911. Some new North American Ixodidae with notes on other species. Proc. Biol. Soc. Wash. **24**: 197–208.

COUES, E. ed. 1897. The manuscript journals of Alexander Henry and David Thompson, 1799–1814. Harper, New York.

FERRIS, W. A. 1940. Life in the Rocky Mountains. Old West Publishing Co., Denver.

GREEN, R. G. and J. E. SHILLINGER. 1934. Michigan wild-life disease investigation, October, 1933. Minn. Wildlife Disease Investigation, Vol. 1.

HAMMERSLAND, H. L. and E. M. JONESCHILD. 1940. Tularemia in beaver. Jour. Amer. Vet. Med. Assoc. **96**: 96–97.

JELLISON, W. L. *et al.* 1942. Epizootic tularemia in the beaver, *Castor canadensis*, and the contamination of stream water with *Pasteurella tularensis*. Amer. Jour. Hygiene. **36**: 168–182.

JUDD, W. W. 1954. Some records of ectoparasitic Acarina and Insecta from mammals in Ontario. Jour. Parasit. **40**: 483–484.

KOHLS, G. M. U.S. Public Health Service, Rocky Mountain Laboratory, Hamilton, Mont. Personal communication.

KNUDSEN, G. J. 1953. Beaver die-off. Wis. Cons. Bull. **18**: 20–23.

LABZOFFSKY, N. A. and J. A. F. SPRENT. 1952. Tularemia among beaver and muskrat in Ontario. Can. Jour. Med. Sci. **30**: 250–255.

SCOTT, J. W. 1940. Natural occurrence of tularemia in beaver and its transmission to man. Science. **91**: 263–264.

STENLUND, M. H. 1953. Report of Minnesota beaver die-off, 1951–52. Jour. Wildl. Mgt. **17**: 376–377.

TANNER, JOHN. 1830. The narrative of the captivity and adventures of John Tanner during thirty years of residence among the Indians in the interior of North America. G. & C. & H. Carvill, New York.

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RELATION OF ECOLOGICAL SUCCESSION TO FARM GAME IN CUMBERLAND COUNTY IN THE VIRGINIA PIEDMONT [1]

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Agricultural census data indicate that approximately 50,000 acres of land per year have been retired from agricultural use in the past 50 years in Virginia. Today there is an estimated total of approximately 2,500,000 acres of such land in the Old Dominion (Anon., 1950). This land is potentially of great importance to the State for the production of wildlife, which can be given top priority on such land. For purposes of definition, abandoned land is considered to be cropland which is no longer being cultivated and on which there has been no major disturbance (either by man, by livestock, or by other causes) since the time of last cultivation.

The principal objectives of this investigation were to determine the trend of natural plant succession on abandoned fields in a representative county of the Virginia Piedmont and to attempt to interpret this information in terms of practical wildlife management. It is thought that if these successional data are correctly analyzed, such an analysis should indicate in general what has happened, is happening, or may be expected to happen to the flora and fauna on much of the approximately 2,500,000 acres of abandoned land in Virginia.

The flora was examined *in toto* and the general population trends of the bobwhite quail (*Colinus virginianus marilandicus*) and the cottontail rabbit (*Sylvilagus floridanus mallurus*) were investigated on abandoned croplands ranging in age from one to 25 years.

Cumberland County, in the approximate center of Virginia, was selected as an investigational area because it contained ample acreage of abandoned cropland. Records of the Production and Marketing Administration indicate that Cumberland County has 12,306 acres, or 6.7 per cent of the total land area of 184,320 acres, of abandoned land. In addition, for comparative studies it contained about 16,000 acres of publicly-owned State Forest land on which game management practices are being carried out, largely on abandoned cropland.

The causes of succession on abandoned land were not given emphasis in this investigation as this aspect has been reported upon, for example, by Crafton and Wells (1934), Billings (1938), and Keever (1950).

One of the most comprehensive analyses of plant succession of the Piedmont of North Carolina was made by Oosting (1942) who described the plant community structure and changes which took place on varying-aged abandoned croplands on the Duke Forest. Bard (1952), working in the Piedmont of New Jersey, found that Oosting's generalizations applied, but that the dominants during the first three years differed from those present in North Carolina. Further south, Bonck and Penfound (1945) described plant succession on abandoned sugar cane fields in the vicinity of New Orleans, Louisiana.

Comparatively few investigators have attempted to determine the influence of the various stages of plant succession upon wild animal populations. Notable exceptions to this include Grange (1949), Bump (1950), Linduska (1950), Beckwith (1941), Lay (1952), and Cady (1944).

Methods

Abandoned fields were first located by the use of aerial photographs. Once a field was

[1] Release No. 55–1 of the Virginia Cooperative Wildlife Research Unit (Virginia Polytechnic Institute, Virginia Commission of Game and Inland Fisheries, Wildlife Management Institute and Fish and Wildlife Service, cooperating). This report, an abstract of a PhD dissertation, covers part of an investigation largely financed by the Virginia Agricultural Experiment Station (Projects S-150 and S-040). Grateful acknowledgment is made to Dr. H. N. Young, Director for the support of this study. It is a pleasure to thank R. D. McDowell and W. C. Newman for field assistance. A. B. Massey and H. S. Mosby gave general supervision of the field investigations and critically reviewed this manuscript.

located on a photograph, it was inspected on the ground and its ownership, treatment, and age of abandonment established, where possible. A total of 172 abandoned cropland fields was inspected, of which sufficient historical data were obtained on 65 fields to permit their use in the detailed plant and animal studies.

The objectives of the investigation, the number of fields investigated, and the limitation of time and personnel did not permit the use of a statistically sound random sampling procedure. All plant sampling was done by means of quadrats which measured 4.66 feet on each side and represented 0.002 of an acre per quadrat. Quadrats were laid out on the ground by means of a folding frame and the number of each plant species which appeared was recorded. In the sampling of each field, quadrats were distributed at 50-foot intervals along a line crossing it from corner to corner along its greatest diagonal dimension. It was thought that a mechanical sampling procedure of this type was a practical approach to determining the qualitative trend of plant succession.

"Density", "frequency" and "occurrence" were computed for each plant species in each of the fields studied. Density of a species was computed as the average number of stems of a species found in the total of all quadrats taken in that field; frequency was calculated as the percentage of the total quadrats of a field in which a species occurred and occurrence was calculated as the percentage of the total of all stems in all quadrats of the same category. Each of these three methods of indicating abundance of plant species has deficiencies in presenting the successional picture. Percentage of occurrence appears to be the least objectionable and this method of indicating plant abundance is used in this paper.

Three fields were selected from each of the age groups from one to 10 years, three from 15-year-old fields, three from 20-year-old fields and three from 25-year-old fields. Thirty-nine fields were included in the quadrat studies and a total of 362 quadrats was examined. Identification of all plants was made to species with the exception of some of the more complex genera of the Compositae.

In fields studied, those from one to 10 years of age contained only one vegetable stratum, as woody growth during this period made only initial invasion and had not progressed appreciably. In the 15-, 20-, and 25-year-old fields, three strata were clearly recognized; namely: (1) overstory trees, (2) understory trees, shrubs and vines, and (3) herbs.

It was felt that a single-size quadrat (0.002 acre) would suffice to indicate successional trends of all three strata. Under the sampling procedure used, it cannot be demonstrated statistically that these successional data are indicative of the successional trend in the entire county or in the Piedmont Region; however, it is the opinion of the writer, based on extensive observations in Cumberland County and in the Piedmont in general, that the data obtained are representative of the trend of plant succession in most of the Piedmont of Virginia.

PLANT TRENDS

The following discussion is a generalized summary of the trend of plant succession which took place on abandoned cropland for the first 25 years following the removal of these fields from agricultural usage. In Cumberland County in general, surface erosion has been relatively great, both on abandoned fields and fields presently cultivated. Erosion plays a slight role in the trend of secondary succession on abandoned fields but since it is so widespread, it was not given particular emphasis during this study. No consistent correlation was evident between different soil types in the trend of secondary plant succession. It should be stated, however, that most abandoned fields in Piedmont Virginia are deficient in soil fertility; a majority of such fields were retired from agriculture due to the fact that they were on the poorer soils.

The trends of plant succession in fields which have been abandoned from agricultural use for various periods of time are briefly summarized below. In this summary, those plants which are of importance as sources of food and cover for wildlife, or those plants which dominate and later exclude such valuable wildlife plants, are emphasized.

The one-year-old abandoned cropland field is dominated by crabgrass (*Digitaria sanguinalis*) which comprised 48 per cent of the total plants present in the fields studied. Korean lespedeza (*Lespedeza stipulacea*, 10.3

per cent) was the second most abundant species. The abundance of Korean lespedeza is largely dependent upon the use of the field during the last crop season prior to abandonment. Horseweed (*Erigeron canadense*) formed one of the more obvious dominants in the one-year field and comprised 7.8 per cent of the total plants. Horseweed, in combination with crabgrass, forms a two-species complex which characterizes such fields. Woody species, tulip tree (*Liriodenron tulipifera*), persimmon (*Diospyros virginiana*), and sassafras (*Sassafras albidum*) sometimes make an appearance at this stage and may usually be attributed to sprout growth from poorly cleared land. The establishment of Virginia pine (*Pinus virginiana*) seedlings in one-year fields is apparently rare and no case of this type was encountered in the fields investigated.

Crabgrass continues as the dominant species in the 2-year fields from the standpoint of percentage composition. It was the most widely distributed plant, comprising 15.5 per cent of the total plants; whereas its codominant, horseweed, of the one-year fields, had become much less abundant. These two species may not now be considered as dominants in height stratification because they are greatly exceeded in height by ragweed (*Ambrosia artemisiifolia*) and aster (*Aster ericoides*) which make their appearance at this age of abandonment. Aster is the more important of the two species but, on soils low in nitrate and carbonates, ragweed becomes the more important. Korean lespedeza persists well at this age and constituted 8.6 per cent of the total plants recorded. Another legume, partridge pea (*Cassia nictitans*), assumes some importance in the 2-year field in which it made up 6.4 per cent of the plants. Several other legumes are also present. Hardwood species, including tulip tree, persimmon, and sweet gum (*Liquidambar styraciflua*) make their appearance as seedlings.

In the third year following abandonment, broomsedge (*Andropogon virginicus*) becomes the dominant plant and remains so for the next few years. Goldenrods (*Solidago* spp.) begin to make an appearance at this time and for the next year or two persist with broomsedge. The important quail food plants, Korean lespedeza and ragweed, occur in good quantities. A number of other quail foods (*Lespedeza* spp., *Desmodium* spp.) are present in limited amounts. Virginia pine does not make a marked invasion at this age but may be found as widely scattered seedlings.

The 4-year field becomes dominated by broomsedge, other plants being present only in proportion to their ability to compete and survive in competition with this grass. Korean lespedeza and ragweed are still present in quantities sufficient to prove attractive to certain wildlife species. Buttonweed (*Diodia teres*) and plantain (*Plantago aristida*), erosion indicators, are found in the 4-year fields where the broomsedge has not become completely established. A number of mixed legumes occur despite the competition. Virginia pine has, in many cases, become fairly well established by this time although this species usually accomplishes its most rapid and complete invasion 5 or 6 years after abandonment.

The 5-year field is still dominated by broomsedge, although Virginia pine makes a rapid invasion at this age, representing 3.6 per cent of the total plants in the fields studied and being the fifth most abundant species. At this age of abandonment, pine seedlings may vary in height from one inch to one foot. Growth of pine is rapid from this age on, and there is a steady increase in the number of pine in the field. Sassafras and persimmon also occur as scattered plants.

Broomsedge decreases slightly in percentage composition in the sixth year as there is an increase in the growth and establishment of Virginia pine. Pine advances rapidly and is the second most important species in percentage composition. Korean lespedeza, partridge pea, and ragweed are present in limited amounts. In the fields studied, all were characterized by a mixture of shrubs which previously had been found in none of the younger-age fields. Among these shrubs were sumac (*Rhus copallina*) and blackberries (*Rubus* spp.) which occurred in a few isolated clumps. These fields contain a good representation of asters, holdovers from younger-age fields. Goldenrod occurs in approximately the same abundance as does aster. The 6-year fields studied were characterized by a much heavier growth of young hardwood species, including white oak (*Quercus alba*), sassafras, tulip tree, black gum (*Nyssa sylvatica*), sweet gum, and willow oak (*Quercus phellos*). Most of these

species occur as isolated plants and are not really important components of the 6-year field flora.

After the fifth and sixth years of abandonment, the general trend is toward the pure pine stand. As the pines rapidly invade the fields and increase in diameter, other plant species gradually are crowded out. By the tenth year following abandonment, the pines begin to dominate all other species and, by the fifteenth year, pine has formed a definite overstory. The understory at this stage is composed of mixed hardwood species which remain subordinate to the pine throughout its development. The ground cover at 15 years is composed of a scattering of various herbaceous species and a few shrubs and vines. Some of these plants produce wildlife food but, in general, they appear in only very limited quantities. The ground cover is, for the most part, too sparse to be of any cover value to wildlife species.

The 25-year field was the oldest considered during this study. At this stage of succession, the field is characterized by the same overstory of pine as found in the 15-year fields. The individual trees, however, have made rapid growth and form a closed canopy under average conditions. The same general conditions persist until much later in the life of the stand with a gradual reduction in the herbaceous growth underneath the woody species.

The floristic composition of the various-aged fields indicated that those from one through 25 years of abandonment could be grouped into four successional classes. Such a division was found to be very helpful in the animal studies. A brief description of the floristic composition of these four succession classes is given as follows:

Succession Class I—(Comprised of fields one year old only.) These fields are characterized by a dense growth of herbaceous species. Crabgrass, horseweed, and Korean lespedeza are the major species present. Woody growth has not yet made a regular invasion and wildlife food and cover conditions appear to be good.

Succession Class II—(Comprised of fields 2–4 years old.) These fields are characterized by a number of perennials and reseeding annuals. Ragweed, Korean lespedeza, asters, partridge pea, and goldenrods are important components. Broomsedge begins to assume dominance in the older fields in this group. Invasion by woody species, Virginia pine, sweet gum, tulip tree, and persimmon is beginning to take place.

Succession Class III—(Comprised of fields 5–10 years old.) These fields are dominated by broomsedge, and by remnants of the perennial asters and goldenrods. Virginia pine makes a marked invasion at this time and grows rapidly to an average height of approximately 5 feet.

Succession Class IV—(Comprised of fields 11–25 years old.) These fields are characterized by a rapid development of Virginia pine toward a closed canopy condition. This development of pine is accompanied by an exclusion of most herbaceous species or by a reduction in their numbers. An understory of hardwood species develops under the pine, characterized by dogwood (*Cornus florida*) and red bud (*Cercis canadensis*).

ANIMAL TRENDS

From the standpoint of the wildlife manager, ecological succession is most valuable when it is interpreted in terms of its relationship to wildlife management practices. It appears that the wildlife management value of any successional stage is dependent upon the capacity of that stage to satisfy three conditions: (1) to provide an adequate food supply during the most critical season, (2) to furnish shelter from natural enemies in the form of suitable cover, and (3) to furnish shelter from the elements.

The first of these conditions, an adequate food supply, is of considerable importance in the utilization of a field by any wildlife species. For this reason, the abandoned fields studied were classified on the basis of the food availability for the bobwhite quail and the cottontail rabbit. Baldwin and Handley (1946) found that the lespedezas (*Lespedeza* spp.), beggar weed, partridge pea, ragweed, and oaks (*Quercus* spp.) were the five most important quail foods in the Piedmont of Virginia. Therefore, the food conditions of the fields in each of the successional classes were evaluated as to their production of the first four of these foods. Oaks had not matured sufficiently to be of any food producing value to wildlife up to 25 years following abandonment. The per-

centage occurrence of each of these four plant foods is presented in Table 1 for the

TABLE 1.—PERCENTAGE OCCURRENCE OF FOUR IMPORTANT QUAIL FOODS IN 39 ABANDONED CROPLAND FIELDS. CUMBERLAND COUNTY, VIRGINIA, 1953

Age of abandonment	Lespedezas	Beggarweed	Partridge pea	Ragweed	Total
1.....	12.1	1.1	1.3	2.3	16.8
2.....	10.0	2.0	6.4	10.1	28.5
3.....	13.6	0.0	4.9	6.7	25.2
4.....	6.2	5.4	2.7	3.4	17.7
5.....	11.4	2.2	3.4	3.4	20.4
6.....	8.3	2.3	3.8	4.7	19.1
7.....	6.4	2.1	4.5	3.1	16.1
8.....	14.6	8.0	4.2	2.2	29.0
9.....	16.6	1.6	0.0	0.0	18.2
10.....	20.8	4.8	7.0	0.0	32.6
15.....	10.3	7.0	0.0	0.0	17.3
20.....	10.2	4.1	8.0	0.0	22.3
25.....	14.3	5.8	0.0	0.0	20.1

fields of each age for which quadrat studies were made. The length of time which one might expect these important quail foods to appear in abandoned fields is a practical consideration from the management standpoint, since wildlife management should utilize techniques to maintain fields in the stage at which game food is most abundant. It may appear from these data that there is a good quantity of quail foods present at all ages of abandonment; however, this is not the case. The percentage occurrence of the four most important quail foods in the 2-year fields was 28.5 per cent of the total plants present whereas in the 20-year field this proportion was 20.1 per cent. It should be emphasized that there are many more stems per acre in young fields than in older fields as a Virginia pine plant is counted with the same relative value as one plant of Korean lespedeza. Thus, the proportion of important quail foods may be large in older fields but the actual number of stems per acre may be insignificant. For example, ragweed virtually disappears from a field after the seventh year of abandonment, and the equally important Korean lespedeza disappears after the tenth year. Once these two species disappear from a field it loses much of its attractive value for quail. It is the opinion of the writer, based on field interpretation of the quadrat data, that abandoned fields, from the standpoint of available food, are most attractive to quail from one to two years after abandonment, of some attraction from four to 10 years later, but lose most of their value after this time. Many of the older age fields may prove attractive as roosting or nesting areas for quail and, with a little effort, could be managed to produce sufficient food.

It would appear from the data in Table 1 that adequate food would be present in all of the different age classes but this is not the case for the reasons just enumerated. Quantitative cover measurements were not made in the various fields although this factor must be given consideration before definite conclusions may be drawn as to the value of a field for quail and rabbits. Percentage occurrence of herbaceous species, trees, shrubs, and vines in the fields of each age is presented in Table 2. It is apparent

TABLE 2.—PERCENTAGE OCCURRENCE OF HERBS, VINES, SHRUBS, AND TREES IN 39 CROPLAND FIELDS ABANDONED FOR DIFFERENT NUMBERS OF YEARS (THREE FIELDS IN EACH AGE GROUP)

Age of field	Herbs	Vines	Shrubs	Trees
1.....	98.7	0.9	0.0	0.4
2.....	95.9	2.4	1.1	0.6
3.....	94.5	2.9	1.4	1.2
4.....	92.4	3.0	1.5	3.1
5.....	93.1	1.6	0.5	4.8
6.....	83.1	2.6	3.1	11.2
7.....	75.7	4.3	4.6	15.4
8.....	66.6	4.4	8.9	20.1
9.....	63.6	9.2	17.2	10.0
10.....	65.3	6.3	7.3	21.1
15.....	51.0	11.4	6.5	31.1
20.....	55.6	9.5	6.6	28.3
25.....	42.2	16.1	10.9	30.8

upon examination of the succession data that ground cover becomes very scarce after the fifteenth year of abandonment. When pine begins to form a closed canopy, ground cover becomes less desirable for the cottontail rabbit and bobwhite quail. Since personal observations and the data of other workers indicate that the cottontail rabbit obtains a relatively large portion of its food from cultivated land, it would be difficult to classify abandoned fields on the basis of the more important rabbit foods. Cursory examination of the succession data seems to indicate that fields of the same general age, one to three years of age, are most suitable for rabbits from the standpoint of available food and cover. Cover conditions remain relatively good for rabbits through the tenth year of abandonment when the ground cover becomes less abundant.

Suitability of a field for a game species can perhaps best be determined by the amount of use made of that particular field by the species in question. This utilization was measured during this study by means of trap lines and walking census lines for rabbits and by similar census lines for quail. In collecting trapping data on rabbit use of fields in the various successional stages, the number of traps available was the principal factor governing the selection of fields to be investigated. Fields were selected on the basis of the four major successional classes previously described. One field was selected in successional Class I; two in Class II; one in Class III; and two in Class IV. These fields were each typical, so far as the writer could determine, of the floristic composition of the successional class in which they fell.

Box traps were used in this work. As a matter of convenience and to establish a standard location, all trap lines were placed 50 feet from the edge of the field beginning nearest the best pine seed source. Traps were placed 50 feet apart, with the first trap being placed 50 feet from the edge of the field. Lines were placed parallel to the edge of the field in every case with the last trap being the one lying nearest to the last 50-foot interval within the field. Trap lines were set in each field for a period of 10 nights each month from September, 1953, through January, 1954. Each trapped rabbit was ear-tagged and the tail colored with a solution of dye.

Game census lines were walked in abandoned fields and all flushed rabbits and quail were recorded. Lines were walked each month from September, 1953, through January, 1954, in a number of fields representing each of the major succession types. Five fields were selected from each of the four major succession types, giving a total of 20 fields in which lines were walked. The order in which these census lines were walked each month was determined from a table of random numbers. Parallel lines were walked 15 feet apart until the entire field was covered. The first line was begun 15 feet in from any boundary of the field, as the starting point was not considered to be of particular importance since the entire field was to be covered. Once the starting point was established, however, this point was used each month for the remainder of the census period.

The trap lines in fields of the four major successional classes resulted in the capture of 118 rabbits. The results of live trapping of rabbits to determine utilization of the several successional stages are shown in Table 3. Because of the small number of fields investigated, it was impractical to determine statistically if there were any significant differences in the trapping results obtained in the different successional classes. It appears, however, based on visual appraisal of the data, that there was a slight difference. If these figures may be accepted as indicative of utilization of these fields, it appears that the greatest use by rabbits was made of the fields in the 2- to 4-year-old group (Succession Class II). It appears from the data that the next highest degree of use was found in the 5- to 10-year group (Class III). The lowest degree of use appeared to be in the 11- to 25-year-old group (Succession Class IV).

TABLE 3.—RABBITS TRAPPED IN ECOLOGICAL SUCCESSION CLASSES FROM SEPTEMBER, 1953, THROUGH JANUARY, 1954, CUMBERLAND COUNTY, VIRGINIA

Successional Class	Rabbits Captured	No. of Traps	Trap Nights	Trap nights per rabbit
September				
Class I	1	12	120	120
II	3	23	230	77
III	0	11	110	...
IV	0	28	280	...
October				
Class I	1	12	120	120
II	7	23	230	33
III	2	11	110	55
IV	1	28	280	280
November				
Class I	3	12	120	40
II	13	23	230	18
III	3	11	110	37
IV	5	28	280	56
December				
Class I	6	12	120	20
II	23	23	230	10
III	4	11	110	28
IV	8	28	280	35
January				
Class I	4	12	120	30
II	17	23	230	14
III	7	11	110	16
IV	8	28	280	35

The number of quail flushed on the census lines was too small to be analyzed statisti-

TABLE 4.—RABBITS FLUSHED ON WALKING GAME CENSUS LINES EACH MONTH IN 20 ABANDONED CROPLAND FIELDS FROM SEPTEMBER, 1953, THROUGH JANUARY, 1954, CUMBERLAND COUNTY, VIRGINIA

Successional Class*	Feet of Census Line Walked	Rabbits Flushed	Rabbits per 1000 Feet of Line
September			
Class I.....	16,098	3	0.19
II.....	53,598	10	0.19
III.....	37,285	3	0.08
IV.....	55,223	3	0.05
October			
Class I.....	16,098	3	0.19
II.....	53,598	13	0.24
III.....	37,285	1	0.03
IV.....	55,223	2	0.04
November			
Class I.....	16,098	4	0.23
II.....	53,598	8	0.15
III.....	37,285	2	0.05
IV.....	55,223	0	....
December			
Class I.....	16,098	2	0.12
II.....	53,598	8	0.15
III.....	37,285	2	0.05
IV.....	55,223	2	0.04
January			
Class I.....	16,098	1	0.06
II.....	53,598	8	0.15
III.....	37,285	3	0.08
IV.....	55,223	1	0.02

* Each class is a summary for five fields.

cally, but it appears that the number seen was greatest in Succession Class I.

Data on rabbits flushed are presented in Table 4. Results of an analysis of variance of the rabbit flush data show a very significant difference (99% probability level) between classes and no significant difference (95% probability level) between months. Also, there was no significant interaction on months and classes. Using a test derived by Duncan (1953) a significant difference was found between Succession Classes II and IV, II and III, and I and IV. There was no significant difference between any other combination of classes.

Data developed from census lines, trapping, vegetation analyses, and observations indicate that abandoned fields are most desirable for quail and rabbits during the first, second, third, and fourth years following abandonment. On the basis of these data, the maintenance of abandoned fields at these ages of vegetational succession would be a desirable wildlife managment objective.

In general, it appears that wildlife habitat manipulations, whether food plantings, large scale field plantings, or forest clearings, should be undertaken with a full knowledge of the importance of the successional principles involved. Data gathered in this investigation indicate that plant succession on idle, or abandoned, land should not be permitted to progress beyond the fifth year of abandonment if maximum farm game production is desired.

SUMMARY AND CONCLUSIONS

1. Quadrat studies in the Piedmont region of Virginia indicated that the trend of secondary plant succession on abandoned fields might be classified in four major groups as follows: Succession Class I (one-year fields), Succession Class II (2- to 4-year fields), Succession Class III (5- to 10-year fields), and Succession Class IV (11- to 25-year fields).

2. On the basis of rabbits live-trapped in each of the successional classes, it appears that there was more utilization of fields in the 2- to 4-year-old group (Class II), followed by fields in the 5- to 10-year-old group (Class III). Lowest utilization was in the 11- to 25-year group (Class IV).

3. Census lines for quail gave results which were too small to be analyzed by statistical methods. Results of an analysis of variance of rabbit flush data show a very significant difference (99% probability level) between successional classes, but no significant difference (95% probability level) between months. Also, there was no significant interaction of months and classes. The test indicated significant differences between Classes II and IV, II and III, and I and IV. There was no significant difference between any other combination of classes.

4. Census line, trapping, and quadrat data all indicated that abandoned fields were most desirable for quail and rabbits during the first, second, third, and fourth years following abandonment. The maintenance of abandoned fields at these ages of vegetational succession would be a valuable wildlife management practice. Efforts should be directed toward altering and holding plant succession in Classes I and II.

LITERATURE CITED

ANON. 1950. United States census of agriculture, 17th census. Bureau of the Census, U. S. Dept. of Commerce, Wash., D. C.

BALDWIN, W. P., JR. and C. O. HANDLEY. 1946. Winter food of the bobwhite quail in Virginia. Jour. Wildl. Mgt., **10**: 142–149.

BARD, G. E. 1952. Secondary succession on the Piedmont of New Jersey. Ecol. Mono., **22**: 195–215.

BECKWITH, S. L. 1941. Ecological succession on abandoned farmlands and its relationship to wildlife management. Ph.D. dissertation, University of Mich., Ann Arbor.

BONCK, J. and W. T. PENFOUND. 1945. Plant succession on abandoned farmland in the vicinity of New Orleans, La. Amer. Midl. Nat., **33**: 520–529.

BILLINGS, W. D. 1938. The structure and development of old field short leaf pine stands and certain associated physical properties of the soil. Ecol. Mono., **8**: 437–499.

BUMP, G. 1950. Wildlife habitat changes in the Connecticut Hill Game Management Area: their effect on certain species of wildlife over a twenty-year period. Memoir 289, Cornell Univ. Agr. Expt. Sta., Ithaca, N. Y.

CADY, E. R. 1944. Winter quail foods on abandoned farmlands in the Norris Reservoir area. Jour. Tenn. Acad. Sci., **19**: 10–15.

CRAFTON, W. M. and B. W. WELLS. 1934. The old field prisere: an ecological study. Jour. Elisha Mitchell Sci. Soc., **49**: 225–246.

DUNCAN, D. B. 1953. Multiple range and multiple f tests. Tech. Report No. 6, Dept. of Stat. and Stat. Lab., Va. Agr. Expt. Sta., Blacksburg, Va.

GRANGE, W. B. 1949. The way to game abundance. Charles Scribner's Sons, New York. 481 pp.

KEEVER, C. 1950. Causes of succession in old fields of the Piedmont, North Carolina. Ecol. Mono., **20**: 229–250.

LAY, D. W. 1952. Bobwhite quail in relation to land management in the pine woodland type. Fed. Aid Report Series No. 10, Texas Game, Fish and Oyster Comm., Austin, Texas.

LINDUSKA, J. P. 1950. Ecology and land use relations of small mammals on a Michigan farm. Report, Fed. Aid Proj. 2-R, Mich. Dept. of Cons., Lansing, Mich.

OOSTING, H. J. 1942. An ecological analysis of the plant communities of Piedmont, North Carolina. Amer. Midl. Nat., **28**: 1–126.

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REVIEWS

Bird Navigation. By G. V. T. Matthews. Cambridge University Press, New York. vi+141 pages. 1955. $2.50.

"It is curious," writes Matthews, "that although human navigators have for centuries been obtaining their position in unknown areas from the sun's co-ordinates, it is only in the last few years that the possibility of birds doing likewise has been considered." This gem of a book sets forth clearly, carefully and precisely Matthews' own observations and conclusions regarding the sun as a cue to orientation in birds. The book is founded upon his own original researches which started after the war, and which have been carried up to the present, with three of his 1955 papers cited therein. Matthews braces his discussions of sun-awareness against a thorough review of the studies and experiments by others, so that the book, with its 15-page bibliography, is the most important review since Thomson's 1936 summary (A. L. Thomson, 1936, *Ibis*, **6**(3): 472–530). He gives thorough attention to the work of Gustav Kramer, who, with his colleagues, likewise is conducting studies of sun-awareness in birds. Since Matthews' 13 papers and Kramer's 18 publications (only one in our language) have all appeared in European journals, many North American ornithologists have had only a vague idea that important new discoveries were being made, and this book now presents this new information to a wide audience.

The sun may serve as a cue to orientation in two ways. Firstly it functions as a compass by which birds perceive direction; and it is in the experiments of Kramer, with his caged Starlings, that we find the evidence of this 'sun-compass'. Kramer found that "with the sky heavily overcast there was no trace of orientation, but when the cloud dispersed the bird became strongly orientated." In his carefully controlled experiments, Kramer showed how the bird orientated itself by the sun through the day and "the implication was that the birds could make allowance for the regular daily movement of the sun, and that they had some form of 'chronometer' allowing them to measure the passage of time."

Secondly, the sun serves as a cue to the direction of home when a bird is displaced from its familiar range. An awareness of compass direction could not guide a bird home when it was in strange surroundings. But Matthews, working with homing pigeons as well as with wild gulls and shearwaters, shows how his birds had an initial homeward orientation when released in unfamiliar country, and he presents convincing evidence that the birds are cued to the direction of home by the sun. "... the marked homeward orientation shown by pigeons in critical releases in sunny weather deteriorates markedly in conditions of heavy cloud and breaks down completely with overcast skies. ... The homeward orientation of Lesser Black-backed Gulls in sunny conditions gave place to a disorientated scatter in heavily clouded and overcast conditions." Moreover, with the Manx Shearwater, Matthews found that "the same individuals which gave good orientation in sunny conditions would scatter at random with overcast, and vice versa." Matthews concludes that the bird in unfamiliar range must be orientated homeward by its awareness of the change it perceives in the sun-arc and the sun schedule. South of home the arc is higher, north of home, lower. East of home the schedule of the sun is advanced, west of home, retarded relative to local home time. At a distance from home, the bird, according to this sun-arc hypothesis, is aware of the variation in the arc and schedule of the sun and thus perceives the direction of home.

Very important to this hypothesis is the "distance effect" which Matthews examines carefully. For many years it has been known that in experimental homing tests, individuals released far from home may orientate homeward more precisely and return at a greater rate of speed than others of the same kind set free at lesser distances from home. Working with two teams of experienced pigeons, he found that: (1) In birds released 10 miles from home, "a coarse orientation resulted which could be clearly attributed to memory of landmarks since it became generally better at closer distances . . .": (2) In birds released 35 miles from home, there was a "near random scatter, as in the other non-orientated releases with slow returns."; (3) When released at 50 miles from home, "good orientation has been achieved." Close to home, the birds may not be able to perceive the slight change in the sun-arc and schedule; when displaced to unfamiliar range, they must wander at random in search of home. Released at greater distances, the birds may be aware of the more pronounced changes in sun-arc and schedule and thus orientate homeward even though in unfamiliar country. The distance effect is evidence of a type of "grid navigation"; and since it apparently does not operate without the sun, it lends strength to this sun-arc hypothesis.

In presenting his evidence, Matthews does not suggest that the sun is the sole factor in orientation. Having observed the direct homeward orientation when his birds were released on unfamiliar range on a sunny day, and having demonstrated that this homeward orientation broke down when the sun was hidden behind cloud overcast, he found that "when pigeons are very familiar with a release point, after six previous releases there, overcast conditions have no effect at all on initial orientation."

Gustave Kramer also has observed the direct homeward orientation of his experimental birds which he believed to be evidence of some sort of astronomical navigation; and it remains now for other workers on other ranges with different birds to test and re-test this sun-navigation hypothesis. North American biologists will find Geoffrey Matthews' account clearly stated and carefully documented, with 33 excellent line drawings adding much to the clarity of the demonstration. Surely in the literature on bird migration and orientation, which reaches back to the very beginning of man's literary history, this book must stand as a great landmark leading to the eventual solution of this problem of avian navigation, one of the oldest mysteries to mankind.—H. ALBERT HOCHBAUM.

Red Foxes and a Declining Prey Population. By Thomas G. Scott and Willard D. Klimstra. Monograph Series No. 1, Southern Illinois University, Carbondale, Illinois. 1955. 1–123 pp. textfigs.

This is another of the carefully conceived studies carried out at the Iowa Cooperative Wildlife Research Unit. The locale was the Des Moines River Valley in Davis County, Southeast Iowa. Field work covered the period, February 1946 to April 1949.

An original motive of the project was to evaluate the influence of the northern plains red fox on populations of the bobwhite. But an unforeseen circumstance gave a particular significance to the work which is emphasized in this report. It encompassed three years when nearly all of the vertebrate prey of the fox was in decline. Major food items varied from abundance to scarcity, and the authors made good capital of these changing conditions in their investigation of fox and prey dynamics.

The study area comprised a 620-acre state-owned tract and about 2,000 acres of privately owned land. It included rough, largely wooded uplands and more level, farmed lowlands. Fox numbers were relatively stable. A family group occupied the range each year, and there were other families on surrounding land. From fall to spring in this area, foxes were regularly run with hounds, an activity that reached its maximum in April 1948. Fox running was known to occur on 21 days of that month. Evidently a small number of animals supported a surprisingly large amount of hunting, although only one fox was reported killed before the dogs.

Food relationships were interpreted from population trends and seasonal availability of prey, as compared with the contents of 1450 fecal passages collected from trails and dens.

Based on percentage of occurrence, slightly more than half of the food eaten was vertebrate prey (56.4%). Invertebrates constituted 26.2 per cent and plants 17.4 per cent. Trends in food utilization were relatively consistent from year to year in spite of the quantitative decline of important items. In the last year of study, fecal specimens were difficult to find, although the number of foxes remained about the same. At this time two pups appeared to have died of starvation.

There was a marked seasonal transition in food habits. Occurrences of invertebrates (especially grasshoppers) and plants (notably fruits) usually exceeded vertebrates eaten in summer and fall. In cold weather vertebrates predominated. Rabbits and meadow mice were favored items. As numbers of all vertebrate prey declined, meadow mice became relatively less available than other species. As indicated by individuals left uneaten, deer mice were less palatable than meadow mice. Consistent with findings in other studies, the foxes frequently killed moles and shrews but seldom ate them.

Woodchucks were increasingly represented in the food remains each year, even though the population level went down. The authors concluded that no threshold of security was reached for this species, in contrast to the apparent situation with respect to meadow mice. Woodchucks evidently were not vulnerable during the hibernation season.

The increase of rabbits in summer did not result in proportional utilization by the fox. This appeared to correlate with a more general distribution of rabbits at that season, as compared with the tendency to concentrate in winter. Tree squirrels were not plentiful and showed no marked change in population level. They seldom appeared in the food collections.

Birds and plant foods were taken with approximately similar frequency in the three-year period. A substantial portion of bird remains was domestic fowl, evidently originating with a poorly housed chicken flock and dead birds thrown into fields. Better husbandry would have avoided a substantial part of the loss.

Foxes were implicated in the loss of 3 out of 46 quail nests which were under observation during the three breeding seasons. Bobwhite remains were found in 1 of 758 fecal passages collected on trails, and one hen bird was found cached by a fox. Feathers may have indicated predation in one or two other cases. The total effect of foxes on numbers of the bobwhite was inconsequential.

Cold-blooded vertebrates, principally snakes, were an item of low acceptability, and they showed slightly increasing utilization during the period of study.

Findings of particular interest included the apparent "buffer effect" of insects and fruit in summer against fox predation on vertebrates. Horned owls which were making use of the same animal food sources as foxes showed similar responses to availability. When prey populations were low, the hunting of the fox was poorly rewarded, indicating little significant effect on present numbers or future expansion.

In field work and interpretations this study appears to have made use of modern techniques and concepts. It represents good, professional fact-finding in a difficult ecological field. It samples biotic relationships in a limited area for a limited time. The accumulation of such information in our literature steadily builds a fundament of knowledge from which sound principles can be derived.—DURWARD L. ALLEN.

California Grizzly. By Tracy I. Storer and Lloyd P. Tevis, Jr. University of California Press, Berkeley and Los Angeles. 335 pp., illus. 1955. $7.50.

This publication should appeal to both scientist and layman. The California grizzlies are surveyed from the standpoint of their distribution and abundance, taxonomy, habits, relations to the Indian, Spaniard, and American, managed combats with bulls, hunting, and the contributions of the famous James Capen Adams to grizzly lore. The bibliography contains approximately 460 references to books, journals, and newspapers.

The North American grizzlies were split by Merriam into 86 forms, most of which were considered full species. It is a relief to know that by present common consent this number has been reduced greatly through the realization that the skulls of grizzlies from the same locality vary widely. The proposal of Rausch to limit the grizzlies of North America and the Alaskan islands to three subspecies of *Ursus arctos* may be going too far in the other direction. An animal that ranged from northern Mexico to the Arctic had plenty of room for geographical variation.

The authors estimate that at one time California contained 10,000 grizzlies. The last was killed in 1922. Today it is doubtful if more than 1,000 grizzlies, approximately one half of which are to be found in the National Parks, remain in the United States.

The fame of the grizzly rested on its irascibility. Lord of his domain, no interference would be brooked. The literature of the West is replete with ghastly encounters with this bear. Famous trappers like Hugh Glass and Jedediah Smith survived by a miracle. Many a man, in proximity to a grizzly, must have felt like John K. Townsend: "For a moment, I thought my hour had come, and that I was fated to die an inglorious death away from my friends and my kindred." On the other hand the Spaniards in California considered the lassoing

of these bears a princely sport, in which art they were wonderfully adept. The bear, after roping, was killed or saved for pitting against a bull. The authors, fortunately, have quoted extensively from the literature, so that the reader obtains a vivid picture of the encounters. Paraphrasing would have destroyed much of the flavor. The literature has been covered so well that any omission is unexpected; however, G. H. Langsdorff (Voyages and Travels. London. 1814: II, 181) is not mentioned. He recounts that in 1806 Don Louis Arguello sent out eight soldiers who captured a bear to be matched against a bull. The bear died in the night.

The Spaniards were true heirs of the Romans in their love of the bloody sports of the arena. All accounts, however, of battles arranged between bull and bear pale in comparison with the few natural encounters that were witnessed. The description by J. Ross Browne of the struggle between a bull and a bear on the range is extraordinarily tense writing. If a more thrilling description of an encounter between two beasts has been published, I am not aware of it.

An interesting bit of behaviorism is the bear rampant on a field of clover. It is assumed that the grizzly rolled on a grassy plain, kicking his legs into the air to attract cattle within killing distance. It would seem that this bear's experience with cattle had been too brief for this trait to have been evolved deliberately. The grizzly, like other species of bears, had a strong streak of playfulness, no better exemplified than by the account of a wild individual romping with a child. Perhaps, having discovered that its antics attracted the cattle, the technique of securing the prey developed as a matter of course; or, the bear simply took advantage of an opportunity that it did not knowingly create.

Rightly, a chapter is devoted to James Capen Adams. He was one of those extraordinary characters that only the West could produce; fearless, a dead shot, thoroughly acquainted with the habits of wild animals, and completely at home in the wilderness. Through his efforts it was shown that a grizzly, tamed as a cub, would remain docile as an adult, thus exploding the tradition that grizzlies were uniformly ferocious.

The writing is pleasing in style and gives the reader the atmosphere of California in the heyday of the grizzly. Any person desiring stimulation, or vicarious hunting of this bear, cannot do better than read the book.—A. W. SCHORGER.

BRIEFER ARTICLES

A TALLY COUNTER HOLDER

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Tally counters are extremely useful in recording field counts. Many game censuses are made from car or airplane and involve the separate recording of information on sex, species or age class of the animals being considered. Such a census requires the use of several counters, and a method of holding them and keeping them in order is virtually a necessity. Various types of holders such as the one suggested by Grieb (Jour. Wildl. Mgt., 15: 334–335) have been used by the writer. This type of holder is not completely satisfactory in that it must be bolted into position in the vehicle, and one cannot use the counters individually without dismantling the unit. The device shown in Fig. 1 overcomes these objections and has been found satisfactory in all other respects. It is simply a magnetic knife or tool holder that may be purchased in any hardware store. The magnet sticks tightly to any metallic surface while holding the counters firmly in place. The one pictured here is eight inches long and will hold up to four counters.

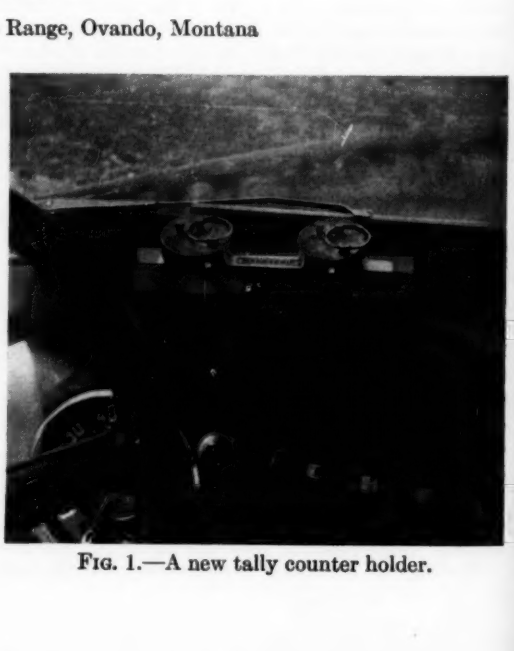

FIG. 1.—A new tally counter holder.

Any one of the counters may be picked off and used individually or may be used while on the magnet. The entire unit may easily be shifted to the most convenient location in the vehicle or moved into another car or airplane. The counters or magnet may be labeled, or the positions of the counters memorized to facilitate recording while looking through binoculars. Counters made of plastic, aluminum and some alloys will not adhere to a magnet. Those used in this study have steel cases which are held firmly in place during the roughest travel.

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FOODS EATEN BY BOBCATS IN MAINE[1]

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This report is based upon the examination of 101 bobcats, *Lynx rufus*, shot or trapped in Maine from September to March during the years 1951–54. The specimens were collected from hunters and trappers and were submitted to the Maine Cooperative Wildlife Research Unit by regional game biologists and wardens of the Department of Inland Fisheries and Game.

Although bobcats are plentiful in much of Maine few specimens have been previously examined. Marston (1942) reported the foods found in ten bobcats. Remains of deer were found in six; snowshoe hare in one. Seventeen specimens from Maine are included in Pollack's (1951) tabulation of the frequency of occurrence of foods found in 208 bobcats taken in New England.

The present series of specimens was collected in the seven counties that include northern and eastern Maine. This region has many heavily-wooded, semi-wilderness areas characterized by mixed forests of spruce, fir, and northern hardwoods. During the period covered by the study no widespread scarcity of the common prey species usually considered food for bobcats was apparent.

Food materials were washed, screened and examined with a binocular microscope to pick out bone fragments, teeth, hair and other remains. Much of the material consisted of hair. It was impossible to examine each hair in detail, but several were removed from each sample. In addition, any hair that appeared different from those in the sample was also removed. These hairs were cleaned and mounted for detailed study with a compound microscope. Another technique which aided the study of hair was an improvised microprojector using a standard compound microscope and a 35 mm. slide projector as described in The Progressive Fish Culturist (Anon. 1953). With this apparatus an image of mounted hairs could be projected upon a screen. The enlarged picture often aided detailed study or comparison with known samples.

Eighty-eight of the 101 stomachs contained food. In 32 specimens the large intestine was present, in addition to the stomach. The frequency of occurrence of the foods found is presented in Table 1.

TABLE 1.—FREQUENCY AND PERCENTAGE FREQUENCY OF OCCURRENCE OF FOOD ITEMS FOUND IN 88 GASTRO-INTESTINAL TRACTS OF THE BOBCAT

Common Name	Scientific Name	Occurrence	
		Frequency	Per cent
ANIMAL			
White-tailed deer	*Odocoileus virginianus*	36	40.9
Snowshoe hare	*Lepus americanus*	19	21.6
Red squirrel	*Tamiasciurus hudsonicus*	11	12.5
Porcupine	*Erethizon dorsatum*	10	11.4
Deer mouse	*Peromyscus* sp.	6	6.8
Field mouse	*Microtus* sp.	6	6.8
Ruffed grouse	*Bonasa umbellus*	6	6.8
Flying squirrel	*Glaucomys sabrinus*	3	3.4
Beaver	*Castor canadensis*	3	3.4
Skunk	*Mephitis* sp.	2	2.3
Chipmunk	*Tamias striatus*	2	2.3
Blue Jay	*Cyanocitta cristata*	2	2.3
Shrew	*Sorex* sp.	1	1.1
Unidentified hair		6	6.8
Unidentified bird		3	3.4
Shrew sp.		3	3.4
Unidentified mouse		2	2.3
Bird feather (probably Passeriform)		1	1.1
PLANT			
Seed	*Prunus* sp.	1	1.1
MISCELLANEOUS			
Woody material (Trap debris)		32	36.4
Paper		3	3.4

[1] Contribution from the Maine Cooperative Wildlife Research Unit, Orono, Maine; Maine Department of Inland Fisheries and Game, University of Maine, Wildlife Management Institute, and the U. S. Fish and Wildlife Service cooperating. Howard L. Mendall, Leader, Maine Cooperative Wildlife Research Unit, and Malcolm W. Coulter, Assistant Leader, gave guidance and advice throughout the study and in the preparation of the report. Horace F. Quick, of the Forestry Department, University of Maine, gave assistance in the identification of hair.

Remains, principally hair, of white-tailed deer were found in approximately 41 per cent of the specimens. This is a higher incidence of deer than has been reported from other studies in the Northeast. In several instances only a few hairs were found; other animals contained up to 100 cc. of deer hair and partially digested flesh. How much of this material represented predation is subject to conjecture. Instances of predation, as well as of bobcats feeding upon deer that died from other causes, are known, including those reported by Marston (1942) and Rollings (1945). The true significance of the relatively high incidence of deer in bobcats in general in the Northeast (Hamilton and Hunter 1939, Marston 1942, Foote 1945, and Pollack 1951) will remain unknown until some researcher has an opportunity to conduct a carefully planned, long term study, in the field, of deer-bobcat relationships.

As a group the rodents made up a significant portion of the foods eaten and occurred in 62 (70 per cent) of the 88 specimens. The larger rodents—snowshoe hares, red squirrels, and porcupines—were most often found.

Although birds did not appear to constitute a large portion of the bobcats' diet, bird remains were present in 12 (13 per cent) of the animals. Grouse were found in 6 specimens. None of the unidentified bird material from three other specimens was believed to be ruffed grouse.

There was no indication that food varied with locality or month during the period studied. All major food species were taken frequently throughout the fall and winter in all areas. However, a larger sample might reveal seasonal or local trends.

It was noted that many specimens contained evidence of only a single food. In some cases, different foods were found in the stomach from those in the large intestine.

The incidence of porcupines is of interest especially in view of the low density of those rodents in northern areas. During the course of other field studies it has become increasingly apparent that in many northern sections porcupines have decreased. In some areas it is difficult to find evidence of porcupines, yet they are taken fairly often by bobcats.

Among the specimens examined no evidence of harmful effects from porcupine quills was apparent. Quills found in the stomach, and especially those present in the large intestine were soft and pliable and were being passed along the digestive tract without difficulty.

LITERATURE CITED

ANONYMOUS. 1953. An improvised microprojector. Prog. Fish Cult., **15**: 162.

FOOTE, L. E. 1945. The Vermont deer herd. State Bull. Pittman-Robertson Series B, Vermont Fish and Game Service, Montpelier.

HAMILTON, W. J. JR. and R. P. HUNTER. 1939. Fall and winter food habits of Vermont bobcats. Jour. Wildl. Mgt., **3**: 99–103.

MARSTON, M. A. 1942. Winter relations of bobcats to white-tailed deer in Maine. Jour. Wildl. Mgt., **6**: 328–337.

POLLACK, M. E. 1951. Food habits of the bobcat in the New England States. Jour. Wildl. Mgt., **15**: 209–213.

ROLLINGS, C. T. 1945. Habits, foods and parasites of the bobcat in Minnesota. Jour. Wildl. Mgt., **9**: 131–145.

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THREE RECORDS OF MALE MONGOLIAN PHEASANTS INCUBATING CLUTCHES

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The Olentangy Wildlife Experiment Station has been established on the Delaware Reservoir Wildlife Area to develop and test methods of improving hunting on public and private lands. Included in the research station's facilities are two 40-acre production units: Unit A is subdivided into eight 5-acre pens; Unit B is not subdivided. Both of these production units are enclosed with an 8-foot chicken wire mesh fence.

Pen 5, in Unit A, contained 12 pheasants per acre with a sex ratio of 1 male to 7 females. Pen 6, in Unit A, had 16 birds per acre in the ratio of 1 cock to 9 hens. The remaining six pens in Unit A contained 25 pheasants per acre with a sex ratio of 1 : 5 in each. Unit B had 6 birds per acre in the ratio of 1 male to 10 females.

One phase of the research carried on at the station during the summer of 1954 required that intensive periodic nest searches be conducted in each of the units. It was during these nest searches that three male Mongolian pheasants (*Phasianus colchicus mongolicus*) were found incubating clutches of eggs.

On May 31, 1954 one of the cock pheasants in Unit B failed to run when approached by a worker. The worker picked up the bird thinking that it was

injured. He observed that the pheasant had been sitting on four eggs which were lying in a small depression. Before the bird was identified, it struggled and managed to free itself, disappearing into heavy cover. Later observations revealed that this male had deserted the nest.

On June 9, 1954 a nest was found in Pen 6, Unit A, which was being incubated by a male Mongolian pheasant. At that time, the nest contained two eggs. It was built in a shallow depression and lined with feathers from the breast of the male. Three days later the nest contained three eggs.

The bird's actions while incubating the eggs were similar to those of a broody hen. He spent little time away from the nest, and when approached while on the nest, he would hiss, fluff his feathers and attack the intruder. This cock continued to incubate the eggs for a period of 14 days. On June 22, 1954 he deserted the nest, and on the following day one of the eggs was found broken in the nest. In hopes that the male would return to the nest, a week was permitted to elapse before the two remaining eggs were examined. On June 30, 1954 the two eggs were opened, but they showed no signs of embryonic development.

On June 11, 1954 a nest was found in Pen 5, Unit A, which was being incubated by a male pheasant. It, too, was built in a shallow depression and contained three eggs. Although feathers from the breast of the cock were found in the depression, they were not used to line the nest.

This bird's actions while incubating the eggs were dissimilar to those of a broody hen. He spent considerable time away from the nest, and when approached while on the nest, he would leave it without showing signs of hostility. The male continued to incubate the eggs for a period of 8 days. On June 18, 1954 he deserted the nest, and on the following day one of the eggs was found broken in the nest. On June 23, 1954 the two remaining eggs were examined, but embryonic development was not apparent.

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IMPROVED TECHNIQUE IN GOOSE TRAPPING WITH CANNON-TYPE NET TRAPS

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It is generally conceded that the Dill cannon-type net trap (H. H. Dill and W. H. Thornsberry. 1950. Jour. Wildl. Mgt. **14**: 132–137) provides the best method for live-trapping geese, wild turkeys, and other large, wary birds. However, this trap is a comparatively recent development and its construction and the technique of its use have undergone steady improvement. At the Pea Island National Wildlife Refuge in coastal North Carolina traps of this type have been in constant use throughout the waterfowl banding season from the fall of 1949 through the late winter of 1954. With them, 2,485 Canada geese and a number of ducks have been caught and banded. Methods have been developed at Pea Island that may be of interest or value to others.

Proper site selection is of top importance. Temporary sites are suitable for duck trapping, but permanent sites are preferable for geese since these birds have a tendency to return time after time, and even year after year, to the same general location. Accessibility of the trapping site to a light truck is highly desirable, since quantities of bait must be hauled in and heavy catches of geese hauled away. Level ground is preferable, but where slopes cannot be avoided the traps should be set to throw downhill. Dry sites should be selected when possible. On wet sites cannons will recoil deep into mud or muck, requiring that they be dug out and reset after each shot; trapped birds may become mud-soaked; propelling charges may become wet; or the net may get so waterlogged or mud-spattered as to fail to throw properly. Trapping adjacent to water is seldom necessary where geese are concerned. Occasionally, when birds are reluctant to leave water, it may be best to locate traps nearby and lead birds to them with bait trails extending from shallow water to upland. Prevailing winds should be taken into consideration, and the trapping site selected so that the trap can be shifted, when necessary, to take advantage of wind direction. Where possible, traps should be fired down wind. It has been found impracticable to fire them against a wind of over twelve miles per hour.

Some trappers have advocated locating traps along a line of existing vegetation to aid concealment. Geese may shy away from such cover, and at Pea Island it has been found best to place the trap in the open. Cannons must be dug in so that not more than three inches of the muzzles project above ground. In soft situations, a piece of wood, 2″ x 4″ x 16″, is used as a backing block behind each cannon. This reduces recoil and provides more power for net propulsion.

The best bait may vary with local feeding habits of the birds. Small seed should be avoided since geese must be baited over a long period of time, and such seed may be subject to heavy removal by small birds. In the Pea Island trapping, shelled corn proved most effective. Initially, trapping sites

are baited heavily over a wide area. As the birds become accustomed to using the site, the bait is gradually drawn in towards the net until it forms a narrow band about one foot wide four feet from the edge of the net. Care should be used to put out sufficient bait to insure a good concentration and a good catch. After the trap has been shot, the site should again be rebaited over a wide area with long lead trails of grain since it has been found that geese become suspicious, and it usually takes about ten days to bait them back for a second shot.

Since an operator must be present to throw the trap, a blind is necessary. To avoid an excessive length of lead wire, which may result in trap failure, these blinds should be within a hundred yards of the trap, preferably within 50 yards. They should be located so that the operator has a perfect view of the trap and the ground immediately in front of it. Originally, Pea Island blinds were constructed of framework and natural vegetation. Operators must be in blinds before daylight and shots are usually made between daylight and 8:00 a.m. Since trapping is done in cold weather and in early morning hours, some thought must be given to the comfort of the operator if he is to function efficiently. Loosely constructed blinds were discarded in favor of those made of framework and tightly covered with tar paper to give protection from wind. Constructed well ahead of the trapping season and properly camouflaged, it was found that geese paid no attention to them.

When the Dill trap was first placed in operation, the blasting caps were wired in series. This resulted in numerous shot failures, so a parallel wiring system was substituted that has worked much more efficiently. If the blind is located less than 150 yards from the trap, two 3-cell hotshot batteries, connected in series, have been found suitable for detonation. If it is necessary to locate blinds at a greater distance, a third battery should be added. Care should be used to keep all electrical connections from touching the damp ground, and small forked sticks have been found best for this purpose. It is necessary to raise them only an inch or two above ground level.

In setting the trap the center cannon should be located exactly midway of the width of the net. Each of the two side guns should be located at points midway between the center gun and the ends of the net and should be pointed outward at 45 degree angles. All three cannons should be elevated 22 degrees for flat land firing. The ground over which the net is to be thrown should be carefully inspected and all sticks, twigs and other debris removed. The net should be carefully inspected for torn places or weak strands and these repaired. Bridle lines should be carefully checked for strength and condition and to see that they are securely fastened to the net and projectiles. Failure to do this can result in loss of the projectiles. The net should be stretched out flat over the trapping site, then folded into position by lapping it back onto itself in a series of folds 22 inches in width. Proper lapping of the net is all-important to good trapping and is a painstaking process. It can be done more easily if projectiles and bridle lines are not allowed to drag during the lapping process. Efforts to pile the net into less than a 22-inch lap may result in its tangling when fired. In the standard type of this trap the trailing edge of the net is held by three stakes, one at either end and one at the center, attached to the net by rubber bands. The efficiency of the trap can be increased by adding two additional stakes, one midway between center stake and each end stake, and attaching them to the net in the same manner. All stakes should be driven into the ground two or three inches behind the trailing edge of the net, leaving approximately three feet of slack in the rubber band connections, which can be camouflaged with sand or leaves. This slack will add three feet to the forward throw of the net and will usually increase the likelihood of a catch as well as its size.

If the standard charge of potassium chlorate and sugar is used, it is advisable to use the granulated rather than the powdered forms of both. Potassium chlorate absorbs moisture readily, with a corresponding loss of strength. For this reason it is best to buy it through a chemical supply firm rather than from a drug store, which may have kept a partly opened carton on hand for some time. In mixing the two, they should never be stirred. The safest method is to pour the two ingredients in a large jar, close the top, and then gently roll it. It should never be shaken violently. Since a mixture loses strength readily, it has been found best to prepare the charges the night before use. Previous recommendations were to place the individual charges in small plastic bags. It was found that five-inch squares of plastic folded over and sealed with Scotch tape served as well. Where charges are subject to excessive moisture conditions, such as heavy rainfall or rising tide, it has been found desirable to place them in a rubber prophylactic, tying this securely and sealing the point where the cap wires emerge with rubber cement. When shooting against wind or under other difficult conditions, the standard load can be safely increased by as much as 20 per cent.

If a catch is not made on the day cannons are loaded, it is recommended that the charge be fired so that the cannons can be freshly loaded before the next attempt. Loads should not be removed manually, since this is too dangerous. It is far safer to fire and reload. In case of misfires, never attempt to remove loads until caps have been made to fire. Dampening wadding, as has been previously recommended by some operators, was found to be a disadvantage. Heavy wadding is not necessary. A single sheet of newspaper should be depressed into the cannon muzzle, the projectile inserted and rammed home. Tamping loads is dangerous and should be avoided. A safe method of wadding is to pour dry sawdust on top of the charge until within a few inches of the muzzle, then insert the projectile.

No tamping is necessary. Nylon nets have been found superior to cotton nets, since they are stronger, weigh less, and vary less in weight from moisture absorption.

Black powder as a propellent instead of potassium chlorate is safer and does not deteriorate so rapidly. The amount used depends upon several factors such as weight of net, wind direction and other variables. For turkey trapping, using a cotton net, 354 grams of FF-g black powder is required. This is equivalent to about 13 drams. If the net is wet, an additional 60 grams is added. An empty .33 Winchester cartridge is used as a convenient measure, and six of these make 354 grams. For goose trapping the charge can be reduced by one-sixth or one-third. After two or three shots, cannon barrels should be swabbed out with a light cylinder oil to remove residue and prevent rusting.

The operator needs patience and good judgment. While birds are supposed to have little sense of smell, it has been found best to avoid smoking if the wind is in the direction of geese near the trap. Since a firing attempt may drive geese away for as much as ten days, it is better to wait patiently for a good catch of at least 25 birds or more before setting off the trap.

If a single operator is used, he should equip himself with a number of light wooden pegs. As soon as the catch has been made he should peg down the leading edge and both ends of the net to prevent the birds caught near its extremities from escaping. A supply of standard-size burlap bags should be on hand, equipped with tie strings or wires. The net should be emptied of its catch as quickly as possible to prevent birds from tangling themselves in it. Only two geese should be placed in each bag. Birds should be removed from the bag, banded and released as quickly as possible. Left in the bags too long, they will develop paralysis of the legs and will be unable to walk or fly for several hours. A game-handling jacket has been designed at the Pea Island Refuge for use in holding geese. This consists of a canvas sleeve which is placed over a single bird. The neck and head and the feet and tail protrude from either end. A drawstring confines the bird to the jacket. The advantages of using this device instead of burlap bags are several, including the elimination of paralysis, reducing injury, and saving time. Also, it is more sanitary.

While there will always be the need to develop special techniques of operating and baiting to fit each locality and varying weather conditions, the above sums up five years of experience in the use of the Dill cannon-type trap. This involved many mistakes and much trial and error. It is hoped that the results of this experience will aid others in its more efficient and safer use.

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RADIO-CONTROLLED FIRING DEVICE FOR THE CANNON-NET TRAP

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Experiments have recently been completed on a radio-controlled firing device for the cannon-net trap. This research was conducted in cooperation with Mr. John E. Dean, Head of the Department of Electrical Engineering, Colorado A. & M. College. The writers wish to thank Mr. Dean for his helpful ideas, support, and wholehearted participation in the project.

Briefly, the advantages of radio control over other methods are that (1) it eliminates the need of wire strung from trapsite to blind, which is always subject to breakage and creates extra work in uncoiling and rewinding; (2) the trap may be fired from any line-of-sight location eliminating the need of a permanent blind. Tests indicated that the cannon could be fired from a car, or even an airplane, at a distance of a mile and one-half (the longest tried).

The necessary equipment other than the net and cannon assembly as described by H. H. Dill and W. H. Thornsberry (1950. Jour. Wildl. Mgt. 14: 132–137) include: (1) the propelling charge which was a 12-gauge shotgun shell reloaded with FFF-g black powder, and primed with a Dupont electric squib; (2) the radio receiver packed in a plywood box with necessary batteries, buried at the trapsite; (3) the portable transmitter.

Specifically, the equipment is composed of the following: one BCR-3 receiver, one BCT-2 transmitter, and one BCR-3 installation kit. This radio gear was purchased from Babcock Radio Engineering Inc., 7942 Woodley Avenue, Van Nuys, California. Also needed are: one Amperite thermostatic delay relay (6.3 V. heater) #6N010, which will give a delay of 10 seconds; one six-volt pilot light; one toggle switch to turn the receiver off and on; three terminals; one seven-prong plug to bring all wiring to a common point; one piece of lucite for mounting terminals (optional); and one set of high-impedance ear-phones for tuning the set. It should be emphasized that the set must be tuned in accordance with directions given in the instruction booklet accompanying the radio gear.

Eveready batteries used in the transmitter were: two #467, 67½-volt batteries; and two, "D" flash-

light batteries. Those used for the receiver were: one #487, 45-volt battery; one #768, 22½-volt battery; two #6, 1½-volt dry cells; and one #411 E, 15-volt (hearing-aid) battery. The firing circuit, which is separate from the receiver, requires one #1461, hot-shot battery.

A schematic drawing of the receiver and firing circuit wiring is given in Figure 1. This is very similar to the detailed instructions given in the booklet accompanying the set, but larger batteries have been substituted in many instances for longer life. In addition, several circuits and pieces of equipment have been added to adapt this device to fire the cannon upon receipt of the proper signal from the transmitter.

As previously mentioned, the firing circuit is separate from the receiver and has its own battery. In order to close this circuit and fire the cannon, the transmitter must send a continuous signal for a period of 10 seconds. This in turn is picked up by the receiver which energizes the heater element of the Amperite thermostatic delay relay. After a period of 10 seconds the delay relay closes, which completes the firing circuit and the cannons are fired. Thus, the delay relay is used to prevent the sensitive receiver from closing the firing circuit by signals created from lightning, from radio controlled model airplanes, or from other electrical noises such as opening and closing transmitter and receiver switches. Without this delay relay, the

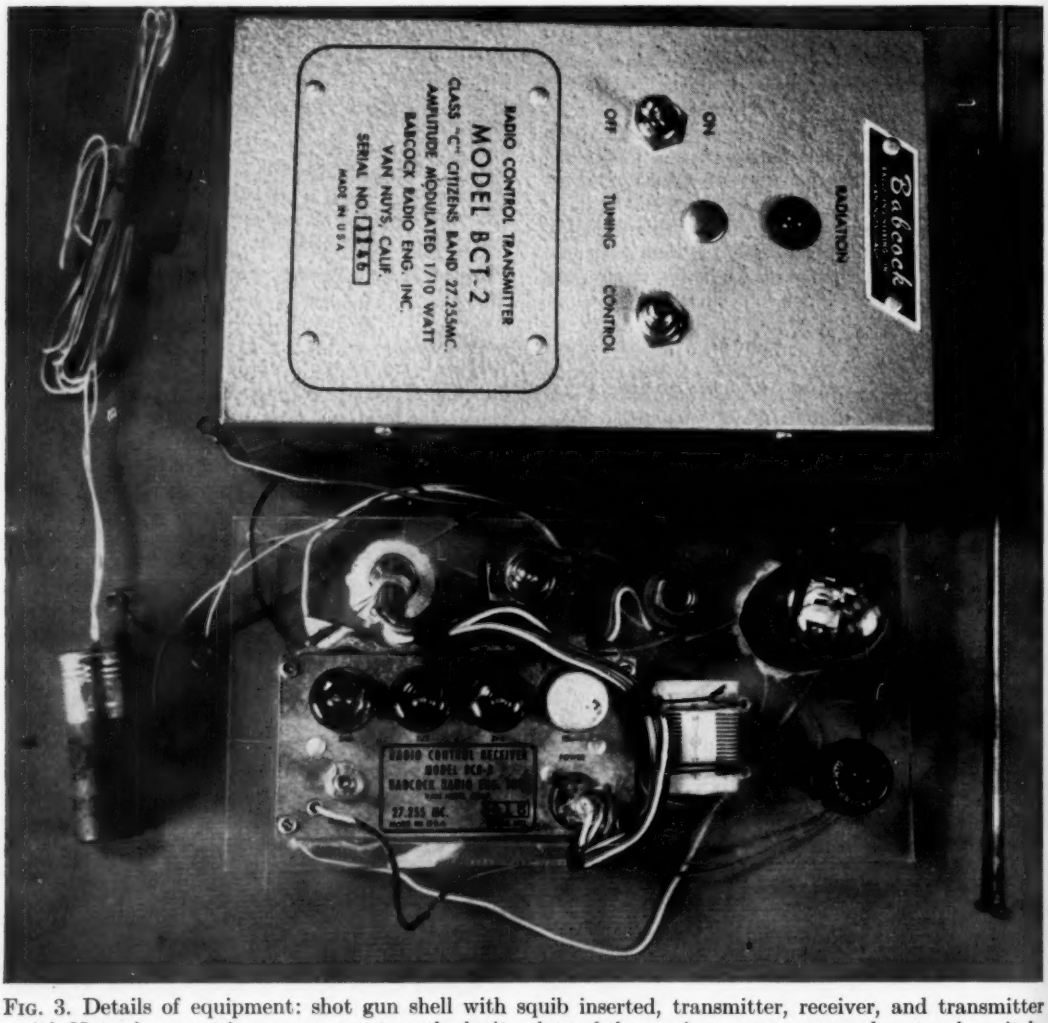

FIG. 3. Details of equipment: shot gun shell with squib inserted, transmitter, receiver, and transmitter aerial. Note the mounting arrangement on the lucite plate of the receiver, seven-prong plug, toggle switch, jack for head phones, 10 second delay relay, pilot light, and hearing-aid battery.

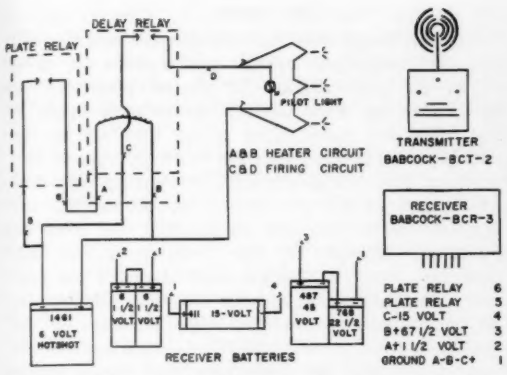

FIG. 1. Schematic drawing of radio firing device for cannon-net trap.

cannon could be fired simply by turning on the set.

One other detail not previously explained is the use of the pilot light. This small light is placed in parallel with the firing circuit, and allows the operation of the set, up to the firing circuit, to be checked before connecting the squib wires.

The radio-controlled firing device has been used to fire Colorado's two traps under a wide variety of conditions and has proven itself entirely satisfactory.

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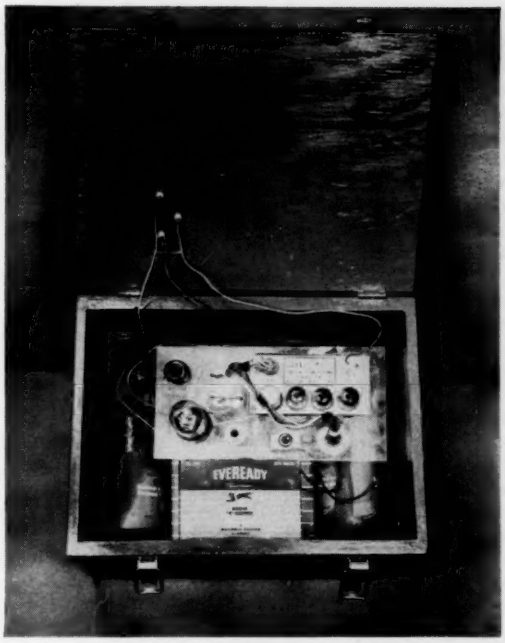

FIG. 2. Plywood box containing the receiver with all necessary batteries (to be buried at the trapsite)

A COMPARATIVE TEST OF THE INVESTIGATOR AS A VARIABLE IN AGING QUAIL

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Several workers have reported on methods for estimating the age of bobwhite quail by progress of the wing molt (Leopold, 1939; Petrides and Nestler, 1943; Petrides, 1949; Thompson and Taber, 1948; Thompson and Kabat, 1950). There is general agreement as to recommended technique, namely, distinguishing adults from juveniles on the basis of the buff-marked primary coverts of the juvenile as contrasted with the relatively solid color of these feathers in the adult. Age of juveniles less than 150 days can be computed on the basis of replacement of primary remiges.

In most studies on the accuracy of aging techniques, attempts have been made to ascertain extent of variability in the juvenile molt. Generally, it has been assumed that adults can be distinguished readily from juveniles; however, Thompson and Kabat (*op. cit.*) point out the possibility of confusing juvenile and adult quail in winter if buffiness of the tip of the covert is used as the sole criterion. No mention seems to have been made in the literature of the occurrence of wings which may defy separation into one age class or the other. Accordingly, the present study was undertaken to learn how much variability in results occurs when several individuals age the same lot of wings.

Participants in the test included Thomas S. Baskett, Leader, Missouri Cooperative Wildlife Research Unit; Eugene Legler, Leader, Wildlife Investigations Project, Tennessee Game and Fish Commission; William B. Robertson, Jr., Project Leader, Illinois Natural History Survey and Illinois Department of Conservation; and the authors. One member of the group had not made quail-age determinations previously; the others had handled up to 1,000 wings per year. Each participant used the same general technique for differentiating adults from juveniles but differed in the use of criteria for computing ages for juveniles.

The 200 quail wings serving as study material

[1] Mr. Fitch is now Biologist-in-Charge of Agricultural Extension Service, Rock-Eagle Lake, Eatonton, Georgia.

were obtained by Fitch as a random sample from the collections of the Alabama Cooperative Wildlife Research Unit at Auburn. They were from birds shot by hunters throughout Alabama during the 1952–53 hunting season. The wings were tagged and numbered and were submitted to each of the biologists for classification. Four of the five individuals determined whether or not the post-nuptial molt had been completed in adult wings. Age of juveniles was computed to the day, up to 150 days; those above 150 days were listed as "150+."

In analyzing results of the test, disagreements in distinguishing juveniles from adults were classed either as (1) obvious errors, (2) questionable wings, or (3) problem wings. "Obvious errors" were construed as caused by incomplete examination. "Questionable wings" were those in which one character indicated one age group, whereas the remaining characters favored the other group. In "problem wings," the diagnostic characters were about evenly divided between both age groups. Findings are presented on the three main points tested: (1) distinguishing adults from juveniles, (2) determining whether post-nuptial molt was complete in adults, and (3) estimating the day-age of juveniles, up to 150 days.

RESULTS

CLASSIFICATION AS ADULT OR JUVENILE—On this point there was disagreement in classification of 16 wings (eight per cent of the sample). On subsequent examination, the participants conceded 11 obvious errors. Of the five remaining wings, two were attributed to "questionable" and three to "problem" specimens. No participant was free from "obvious error" in his classifications. Most recognized the "problem" wings on first examination and listed them as such.

COMPLETION OF POST-NUPTIAL MOLT OF ADULTS—There was agreement on post-nuptial molt for 29 of 53 wings determined to be adult and on 24 there were differences.

AGE OF JUVENILE QUAIL—Accepting the majority verdict, 79 of the juvenile wings were from birds 150 days of age or older. However, all five biologists agreed on only 69 (87 per cent) of these.

According to final judgment, 63 wings were from birds less than 150 days of age. Only four biologists estimated age to the nearest day; the other used a simplified system and recorded age to the nearest week. Because of considerable discrepancy in results obtained by these two methods (88.5 as opposed to 110.4 days average age), results of only those who estimated age to the nearest day are compared. Twenty-five wings (40 per cent) were estimated with a deviation of five days or less; 19 (30 per cent) involved deviations of six to 10 days; 11 (17 per cent) varied by 11 to 20 days; and eight (about 13 per cent) involved deviations greater than 20 days. Average age computation, by the four individuals, for these 63 wings, ranged from 106 to 113 days, a difference of about one week.

DISCUSSION

Since the wings were taken from quail of unknown ages, determinations by the participants are open to question and cannot be classed positively as right or wrong. Five obvious errors were made in classifying the adult wing group and six in the juvenile. In the classification between adults and juveniles there was a disparity among the five participants of 3.5 per cent (from 26 to 29.5 per cent for the adults and 74 to 70.5 per cent for juveniles), though in the breakdown, certain individual analyses showed more than 3.5 per cent error. One individual had six errors in addition to the five wings of doubtful classification. In the combined data, errors tended to cancel each other. Familiarity with the technique and thoroughness in examining appear important in avoiding errors.

In some phases of the study results were governed by the method used. This was particularly true in checking ages of juveniles less than 150 days old. Therefore, it is suggested that any estimate of age should specify the method used. This study has emphasized the need of working with large samples of birds of a known age in order to learn more concerning the extent of molt variations.

Variations in molt seem to have caused most of the differences in classification. Accordingly, the following points appear to need further study:

1. Age class indicated by "light-fringed feather tips" on primary coverts as against "normal" juvenile markings with buff or cream on feather tips and color extending on a point down feather shaft.

2. Irregularities in the molt of Primaries 9 and 10 in juveniles and importance of differences in color shading between unmolted and molted remiges.

3. The difference in color between unmolted remiges of adults following the first post-nuptial molt and those of adults following post-nuptial molts in later years.

4. The ambiguity of "Primaries 9 and 10 *more* rounded . . . . or *more* pointed" as used in existing references.

5. The partial dropping of primary coverts during first breeding molt when some buff-tipped feathers remain with those having uniform color throughout.

6. Use of the feather sheath on primaries as a character for determining status of adult molt and progress of post-juvenile molt.

7. The technique of inspecting wings not only on top but underneath where feathers, covering the point of insertion of the primary into the manus, may be raised to examine thoroughly the replacement of remiges. Measurements made on primaries from the underside of the wing were generally more accurate than those made from the top.

SUMMARY AND CONCLUSIONS

To test the reliability of current techniques, five biologists appraised the ages of 200 quail from a

random sample of wings collected during the 1952–53 hunting season in Alabama. Attempt was made to distinguish adults from juveniles, to ascertain the stage of post-nuptial and post-juvenile molts, and to estimate the age of juveniles according to days or weeks.

Three "problem" wings in this sample had molt characteristics somewhat equally divided between adult and juvenile classes; two wings called "questionable" had all molt characteristics except one of either age group. A 3.5 per cent disparity occurred between investigators in their classification of adult and juvenile age groups. This included not only "problem" and "questionable" wings, but also "obvious errors." Individual differences were greater than 3.5 per cent but cancelled out.

This study emphasizes the need of working with large samples of birds of a known age in order to know more concerning molt variations. Until aging techniques can be refined, it is believed that investigators should be fully familiar with existing methods and their weaknesses. Also, it appears important that reports on aging should indicate clearly the techniques used.

LITERATURE CITED

LEOPOLD, A. S. 1939. Age determination in quail. Jour. Wildl. Mgt. **3**: 261–265.

PETRIDES, G. A. and R. B. NESTLER. 1943. Age determination in juvenile bob-white quail. Am. Mid. Nat. **30**: 774–782.

PETRIDES, G. A. 1949. Notes on age determination in the bobwhite quail. Cooperators' Release 49–3, Texas Coop. Wildl. Unit, College Station, Texas. 1 p.

THOMPSON, D. R. and R. D. TABOR. 1948. Reference tables for dating events in nesting of ring-necked pheasant, bobwhite quail, and Hungarian partridge by aging of broods. Jour. Wildl. Mgt. **12**: 14–19.

THOMPSON, D. R. and C. KABAT. 1950. Wing molt of the bob-white. Wilson Bull. **62**: 20–31.

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BLOOD PARASITES OF SOME MAINE WATERFOWL[1]

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This report summarizes the results from a study of the incidence of blood parasites among wild ducks in Maine. It represents a continuation of a study reported by Nelson and Gashwiler (1941). Since the literature relating to blood parasites in waterfowl has been reviewed recently by Levine and Hanson (1953) in this Journal, no attempt will be made to review the work already conducted by other investigators.

Blood smears were taken from 753 ducks caught in banding traps during the summer months of 1945, 1946, and 1953, and from 61 dead ducks examined during 1953. Blood was collected either from the web of the foot, the tarsal vein or the brachial vein. Smears were made in the field and air dried. They were then fixed for one to three minutes in absolute methanol and stained with a 1–25 parts dilution of Giemsa Stain (National Analine Company) and buffer solution for 45 minutes. (Buffer solution, pH 6.4, contained 3.2 grams of dibasic sodium phosphate and 6.6 grams of mono-basic potassium phosphate per liter of distilled water.) After a washing in tap water the slides were immersed in a buffer bath for 1–2 minutes, washed in running distilled water and air dried.

A microscope equipped with a mechanical stage was used to examine the smears. Each smear was completely examined; this usually required 45 minutes or more.

The incidence of blood parasites among the specimens examined is presented in Tables 1 and 2. Three groups of parasites were found, *viz.*, *Leucocytozoon* spp., *Haemoproteus* spp., and *Microfilaria* spp. Single, double and triple infections involving all possible groupings of the three parasites were found.

It is of interest to note that some slides contained very few parasites. For example, among those showing *Leucocytozoon*, nineteen contained only one gametocyte. In three hundred smears fewer than ten gametocytes were detected. A similar pattern was noted when *Microfilaria* or *Haemoproteus* occurred.

Seventy-three consecutive duplicate blood smears were taken at random. Only 33 pairs of duplicate slides contained like kinds of parasites. In the re-

[1] Contribution from the Maine Cooperative Wildlife Research Unit, Orono, Maine; Maine Department of Inland Fisheries and Game, University of Maine, Wildlife Management Institute, and the U. S. Fish and Wildlife Service cooperating. Appreciation is expressed to Howard L. Mendall, Leader, and Malcolm W. Coulter, Assistant Leader for guidance and assistance during the study and in preparation of the manuscript.

TABLE 1.—THE BLOOD PARASITE INCIDENCE IN BLACK DUCKS OF MAINE FROM ALL SAMPLE AREAS AND FOR THE YEARS 1945, 1946, 1953
Nelson and Gashwiler (1941) Sample Included in Grand Total

	Total Males and Females — 1939–1953								
	No. in Sample	L	M	H	LM*	LH*	MH*	LMH*	NEG.
1939									
Nelson & Gashwiler (1941)	29	26	9	6	8	6	0	0	2
Per cent		89	31	20					
1945									
Penobscot River	100	70	39	3	30	1	2	0	21
1946									
Penobscot River	56	39	13	4	9	2	0	2	14
1953									
Penobscot River	174	149	46	24	28	8	1	11	14
1953									
Corinna Stream	17	12	2	2	2	1	0	0	4
1953									
St. Croix River	61	36	17	4	10	2	0	1	19
Total	437	332	126	43	87	20	3	14	74
Per cent	100	73.7	28.8	9.8	19.9	4.6	0.7	3.2	16.9

TABLE 2.—THE BLOOD PARASITE INCIDENCE IN WOOD DUCKS OF MAINE FROM ALL SAMPLE AREAS AND FOR THE YEARS 1945, 1946, 1953
Nelson and Gashwiler (1941) Sample Included in Grand Total

	Total Males and Females — 1939–1953								
	No. in Sample	L	M	H	LM*	LH*	MH*	LMH*	NEG.
1939									
Nelson & Gashwiler (1941)	77	46	30	50	6	16	7	16	10
Per cent		59	38	64					
1945									
Penobscot River	77	31	26	44	5	8	5	9	12
1946									
Penobscot River	55	26	22	34	7	5	4	8	5
1953									
Penobscot River	107	90	22	29	9	12	3	7	4
1953									
Corinna Stream	183	67	18	127	2	31	5	11	31
Total	422	260	92	284	29	72	24	51	62
Per cent		61.6	21.8	67.3	6.9	17.1	5.7	12.1	14.7

L — *Leucocytozoon*
M — *Microfilaria*
H — *Haemoproteus*
LM — *Leucocytozoon-Microfilaria*
LH — *Leucocytozoon-Haemoproteus*
MH — *Microfilaria-Haemoproteus*
LMH — *Leucocytozoon-Microfilaria-Haemoproteus*
NEG. — No blood parasites found

* Totals for each parasite included under single infections.

maining 40 pairs of smears a variance in the kind of parasites present was indicated. In other words, when two slides were made from one bird, the first smear might contain evidence of *Leucocytozoon* infection. The second smear sometimes contained no *Leucocytozoon* gametocytes or it might reveal the presence of *Haemoproteus* or *Microfilaria*. The lack of uniformity among duplicate sets of smears taken from the same bird further suggests the need for examining a larger sample of blood cells. It also suggests that the parasitism actually may be higher than indicated by the examination of one smear per bird.

This would indicate the need for a careful search of a large number of blood cells before any bird can be considered free of blood parasites.

A difference in the incidence of parasitism was noted between birds taken from two areas that are quite different ecologically. Over 80 per cent of the 107 wood ducks sampled from the Penobscot River were infected with *Leucocytozoon*. Less than 40 per cent of 183 wood ducks from Corinna Stream, 32 air miles distant, contained this parasite.

The Penobscot River may be characterized as a fairly large river with a moderate to strong current. The water is quite clear except near local sources of industrial or domestic pollution. It flows through rather low, boggy, heavily wooded country. By contrast the Corinna area consists of a sluggish stream with dark colored, heavily polluted water. The area includes large expanses of cattail marsh. No attempt was made to sample black fly numbers on these areas, but field personnel agreed that black flies were more annoying on the Penobscot River area. Since the black fly is the principal known vector of *Leucocytozoon* in ducks, this difference in rates of infection between areas suggests the possibility of greater infection in local areas containing higher numbers of black flies.

Forty-five smears made from 8 species of dead ducks showed a low rate of *Leucocytozoon* and *Haemoproteus* infections. However, infections of *Microfilaria* occurred 21 times suggesting the possibility that this type of infection may be successfully detected by smears taken from the heart blood of dead ducks. Love, *et al.* (1953) found filarias in heart blood smears four times as frequently as from peripheral smears.

New Hosts

The following hosts for the parasite indicated are believed to be unreported for the United States.

Microfilaria spp.
Blue-winged Teal (*Anas discors*)
Adult male September 11, 1953
American Goldeneye (*Bucepala clangula*)
(1) Adult female September 10, 1953
(2) Two immature males November 11, 1953

Haemoproteus spp.
Blue-winged Teal (*Anas discors*)
Adult male September 12, 1953
Note: Takos (1947) found *Haemosporidia* in a blue-winged teal taken in Panama.

Leucocytozoon spp.
Bufflehead (*Bucephala albeola*)
Immature male December 5, 1953

Literature Cited

LEVINE, N. D. and H. C. HANSON. 1953. The blood parasites of the Canada goose, *Brata canadensis interior*. Jour. Wildl. Mgt., **17**: 185–196.

LOVE, G. J., S. A. WILKIN and M. H. GOODIN, JR. 1953. Blood parasites of birds collected in southwest Georgia. Jour. Paras., **39**: 52–57.

NELSON, E. C. and J. S. GASHWILER. 1941. Blood parasites of Maine waterfowl. Jour. Wildl. Mgt., **5**: 199–205.

TAKOS, M. J. 1947. Blood parasites of some Panamanian birds. Jour. Paras., **33**: 229–230.

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MIDWINTER COURTSHIP FLIGHTS OF WOODCOCK IN DELAWARE

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On January 8, 1955, the courtship flights of three male woodcocks were witnessed. The temperature was about 25° F. and all standing water was frozen with about one-half inch of ice. The soil was also frozen, and in many places had heaved considerably. Just at dawn the characteristic "peenting" of male woodcocks was heard, and a few moments later the birds were in full courtship flight. They appeared to be staying in sweet gum thickets near a small stream.

This observation was made near Petersburg, about ten miles southwest of Dover, Delaware, just north of the 39° parallel. Apparently these birds were wintering in that vicinity.

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AGE DETERMINATION OF FOXES BY X-RAY OF FOREFEET[1]

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and

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An investigation of breeding, denning and range of the red fox (*Vulpes fulva*) and the gray fox (*Urocyon cinereoargenteus*) in Alabama provided an opportunity to record certain age characteristics. Emphasis was placed on the possibility of identifying young of the year among older foxes by the condition of the epiphyses of the bones in the forefeet as determined by X-ray. Similar X-ray studies of the upper tibial epiphysis of dogs (Schlotthauer and Janes, 1952, Amer. Jour. Vet. Res. **13**(46): 90) have indicated that the "lower femoral and upper tibial epiphyses close at about the age of 10 months."

Two foxes, a red and a gray, were available for these studies during the first fall (1952) of the investigation. The approximate age of each fox was known since they were captured while small. X-rays of the lower radius and ulna of these foxes were made at intervals (Table 1, Animals 2134 and B). The first two X-rays (October and November) showed that cartilage still separated the epiphyses on the radius and ulna from the diaphysis or shaft. The December X-rays showed the epiphyseal plate beginning to disappear but not completely ossified. Unfortunately the red fox escaped in December. An X-ray of the gray fox in early January showed the epiphyses of both the radius and ulna completely ossified.

The following fall two young red foxes and two young gray foxes were used in similar X-ray studies. One of these red foxes also escaped before the investigation was completed. X-rays late in December of the remaining red fox and the grays showed the epiphyses almost completely ossified. X-rays of the fore-feet of seven foxes of unknown ages in January and February showed the epiphyses of both the radius and ulna completely ossified.

It appears that foxes can be classified dependably as adults or as young of the year through November by means of X-rays of the distal epiphyses of the radius and ulna (Figure 1). Some young foxes were distinguishable through most of December. This indicates that ossification is completed in foxes between eight and nine months of age. A faint and incomplete line along the epiphyseal plate is still visible on some foxes in January at which time they are approximately 10 months old. Whelping of foxes in Alabama occurs primarily during late March and April (Sullivan, 1953, M.S. Thesis, Alabama Polytechnic Institute).

To test this technique, 60 fox feet were secured from trappers who were trapping for bounty in connection with a fox control campaign in Lee County, Alabama. Most of these foxes were trapped at or near dens in late summer and fall. The feet were first preserved in alcohol-formalin solution, then dried and pinned on cardboard squares of the same size as the X-ray negatives to be used. As many as 25 feet were X-rayed at one time. By studying the X-rays, it was a simple matter to separate the adult foxes from young of the year. Forty-four (73 per cent) of the 60 foxes were juveniles. Subsequent experiments showed that fox feet can be dried fresh without preservative and kept for several months before they are X-rayed. The clearest negatives were secured when the feet were layed directly on the film holder and X-rayed without being first pinned to cardboard. The foreleg when removed from the fox should be cut off above the joint at the pad, preferably halfway up on the first long bones (radius and ulna).

Successful X-rays were made on "Kodak (no screen) safety film No. 246" with exposures of 60 KVP at 20 MA at one-half-second. All exposures were made at 36". Personnel of the Small Animal Clinic of Alabama Polytechnic Institute did the X-raying.

By X-raying fox feet collected from trappers through November, biologists can determine the ratio of young to old foxes harvested. The final date for collecting feet in different regions should be not later than eight months following the earliest whelping of fox pups in that area. Information on percentage of young should provide a better understanding of productivity of the fox.

This technique has two principal advantages: (1) it permits determination of age without having the entire carcass in hand, and (2) it permits accurate determination of the ratio of young of the year to older foxes for about three months longer

[1] A contribution from the Alabama Cooperative Wildlife Research Unit; jointly sponsored by the Alabama Department of Conservation, Alabama Polytechnic Institute Agricultural Experiment Station, the U. S. Fish and Wildlife Service, and the Wildlife Management Institute.

FIG. 1. Photographic record of X-ray of forefeet of gray foxes. Nos. 1193 and 1195 are from young of the year killed in June. Nos. 1194 and 1196 are from adults killed in July. Note the characteristic enlargement of the epiphyseal cartilage area of the ulna (smaller long bone) in the two young foxes. In the adults the ulna is slim and ossification of the epiphyseal plate in both the radius and ulna is complete.

TABLE 1.—CONDITION OF DISTAL EPIPHYSEAL PLATE OF RADIUS OF FOXES BY MONTHS

Fox No.	Age	Month Captured	Sex	Kind	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
2064.....	Young	Oct.	♀	Gray	..	..	D[1]	..	..	..	..
2126.....	Young	June	♂	Gray	..	..	..	PO[2]	O[4]	..	..
2127.....	Young	June	♀	Gray	..	..	..	PO	O[4]	..	..
2134.....	Young	Sept.	♂	Gray	..	..	D	D	PO	O[3]	..
2041.....	Unknown	Jan.	♂	Gray	..	..	..	..	..	O[4]	..
2042.....	Unknown	Jan.	♀	Gray	..	..	..	..	..	O[4]	..
2050.....	Unknown	Feb.	♀	Gray	..	..	..	..	..	..	O[4]
2056.....	Unknown	Feb.	♀	Gray	..	..	..	..	..	..	O
2128.....	Young	May	♀	Red	..	..	..	PO	O[4]	..	..
2129.....	Young	May	♀	Red	..	..	..	PO	..	..	..
B	Young[5]	April	♂	Red	D	..	D	..	PO[5]	..	..
2091.....	Unknown	Jan.	♀	Red	..	..	..	..	..	O	..
2049.....	Unknown	Feb.	♂	Red	..	..	..	..	..	..	O
2055.....	Unknown	Feb.	♂	Red	..	..	..	..	..	..	O

[1, 2, 3] respectively: Epiphyseal plate, D—distinct, PO—partly ossified, and O—ossified.
[4] Incomplete fine line faintly indicates former cartilaginous connection of shaft and epiphysis of radius.
[5] Estimated age when captured on April 26 was one month. Epiphysis partly ossified at 8½ months.

than can be done dependably from general appearance. This technique accordingly extends the period of age recognition into the fall trapping season when greater numbers are taken.

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THE IMMEDIATE POST-NATAL GROWTH IN THE COLUMBIAN BLACK-TAILED DEER IN RELATION TO THE COMPOSITION OF THE MILK OF THE DOE[1]

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During the past three years, investigations have been in progress on the growth of the Columbian black-tailed deer (*Odocoileus hemionus columbianus*). Recently attention has been directed toward a study of its growth in the immediate post-natal period. For a fuller knowledge of nutritive needs of the suckling fawn and of the lactating doe it was necessary to determine the composition of the milk of the doe.

In 1951, Hagen presented certain values on the chemical composition of a sample of milk from this species obtained in California. Because his report was based on milk recovered *post mortem* from one animal and did not give values for lactose and protein, an attempt has been made to obtain further analytical information. The present paper records this additional data and is designed to relate them to certain aspects of growth of the new-born fawn.

Difficulties associated with procurement of milk from wild species precludes analyses of the large numbers of samples which would enhance the validity of experimental findings. In the present case three samples of milk were obtained. Samples (i) and (ii) were drawn from a captive doe (110 pounds, 3 years) in our stock colony. She had been maintained on a high plane of nutrition throughout gestation and lactation. The samples were taken on the twenty-eighth day of lactation. It is safe to conclude that her milk output was near optimum since the growth rate of her fawn was comparable with rates previously established for this species (Cowan and Wood, 1955).

Sample (i) was obtained by digital manipulation after injection of 40 international units of pituitrin (S) (Parke-Davis & Co.) intravenously into the mammary vein. This induced an immediate "letting down" of milk and permitted the collection of 140

[1] Supported in part by a grant from the National Research Council of Canada.

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ml. The doe was then sacrificed for anatomical studies. The milk remaining in the mammary gland was removed immediately and amounted to 100 ml. This aliquot is designated as sample (ii).

Sample (iii), containing 30 ml., was obtained by game biologist D. J. Robinson by excision of the gland of a wild doe killed for this purpose. The animal appeared to be in the terminal stages of lactation. All samples were preserved with bichloride of mercury and held at 7° C. pending completion of analysis.

The analytical procedures used were those given in "Methods of Analysis" (Anon. 1950). Duplicate determinations were made on samples (i) and (ii) but sample (iii) was inadequate to permit other than single analyses. The results are presented in Table 1. To facilitate comparisons, similar composition figures for the milk of other mammals are included.

TABLE 1.—A COMPARISON OF THE COMPOSITION OF THE MILK OF THE COLUMBIAN BLACK-TAILED DEER WITH THAT OF OTHER MAMMALS*

Species	Constituents as Percentages of the Whole Milk					
	Fat	Protein	Lactose	Ash	Water	Total Solids
Deer (Hagen 1951) ..	8.3	....	....	1.44	79.6	20.4
Deer (Sample (i)	10.5	9.56	3.91	1.56	74.9	25.1
(Sample (ii)....	10.5	8.96	4.67	1.30	74.6	25.4
(Sample (iii) ...	10.2	8.14	4.55	1.62	75.5	24.5
Reindeer.....	22.5	10.3	2.5	1.4	63.3	36.7
Man.....	3.8	1.6	7.0	0.2	87.4	12.6
Horse.....	1.6	2.7	6.1	0.5	89.0	11.0
Sheep.....	6.2	5.4	4.3	0.9	82.9	17.1
Cow.....	4.4	3.8	4.9	0.7	86.2	13.8
Pig.....	7.0	6.0	4.0	0.9	83.0	17.0
Pronghorn Antelope .	13.0	6.9	4.0	1.3	75.1	24.9
Water Buffalo.....	12.0	6.0	4.0	0.9	77.1	22.9

* Espe and Smith (1952).

DISCUSSION

The composition values given in Table 1 are not in close agreement with those reported by Hagen (1951). It is hazardous to speculate on the reason for this disagreement on the basis of so few samples. Stage of lactation can influence the composition of milk but, while Hagen was unable to state the stage of lactation of his doe, on the basis of the date on which the sample was taken it was probably comparable to our own. It is tempting to suggest that the higher fat content recorded here may reflect an adaptation to a more northerly environment. The desirability of further exploration of this aspect of milk composition in wild species is apparent.

The gross caloric content of deer milk has been estimated by calculation from the composition values. On this basis the milk should contain approximately 750 kilo-calories per pound. Unfortunately, insufficient milk was available to determine caloric content by bomb calorimetry. Fat-corrected cow's milk contains 340, sow's milk 550, and milk of the reindeer 1250 kilo-calories per pound. As long ago as 1898-9, Abderhalden noted that the time required for the suckling animal to double its body weight was related to the composition of the milk of its mother. The higher the nutritive content of the milk the more rapid the growth rate and hence the shorter the time required to double body weight. The fawn requires from 10 to 14 days to double its birth weight (Cowan and Wood, 1955), a time in close agreement with the nutritive content of doe's milk when compared with that of other species. Cowan has noted that the growth rate of young reindeer approaches what one would expect from the composition of milk of this species.

To facilitate formulation of a doe-milk substitute for rearing fawns away from the doe, we have computed the approximate caloric contribution made by each of the deer milk constituents. The results of these calculations with those given by Espe and Smith (1952) for other species are shown in Table 2.

TABLE 2.—THE CALORIC VALUE OF MILK CONSTITUENTS RELATIVE TO WHOLE MILK

Species	Fat %*	Protein %*	Lactose %*	Mgms. Protein/ Kilo. Cal.
Deer Sample (i)				
Deer Sample (ii) Mean	60	30	10	54
Deer Sample (iii)				
Reindeer.....	80	16	4	36
Man.....	50	9	41	49
Horse.....	29	22	49	36
Cow.....	53	20	26	51
Sheep.....	59	23	18	55
Pig.....	64	24	12	49
Pronghorn Antelope....	70	21	9	69
Water Buffalo.....	73	16	11	69

* Per cent of calories contributed by the main constituents relative to the caloric content of the whole milk.

The deer and pig show a comparable energy distribution of milk constituents. This is again reflected in the similar growth rate in the young of both species. Since cow's milk is the most probable starting material for the formulation of substitute doe's milk, Table 2 suggests that normal cow's milk should be diluted slightly with water to bring the lactose in line with that of deer milk, then be enriched with fat and protein to raise the level of these constituents to those anticipated in deer milk. Such a formulation might take the form shown in Table 3 and provide a caloric distribution of the basic constituents similar to that of doe's milk.

A formulation similar to that suggested above has been used with some success in rearing fawns from shortly after birth.

Reference to Table 1 and to caloric calculations

TABLE 3.—SUGGESTED MODIFICATION OF COW'S MILK FOR THE FORMULATION OF A DOE'S MILK SUBSTITUTE

Constituent	Gms/ 100 Gms.	Oz/ Pound*	Oz/ Quart*
Cow's Milk (4% fat).....	80	13.0	26.5
Water.....	7	1.1	2.5
Edible Fat (vegetable oil)	7	1.1	2.5
Casein.....	6	0.8	1.5
	100 gms.	16.0 oz.	33.0 oz.

* Values are approximate and have been adjusted to facilitate measurement under field conditions.

made from it reveals that doe milk has, in the nutritional sense, twice the quality of cow milk. As already pointed out, this is associated with rapid growth of the fawn. In a wild species, particularly one in a northern latitude, rapid early growth is an important contribution to survival through the subsequent winter.

Two possible sources exist for nutrients to produce milk of the quality indicated. Under relatively ideal conditions the doe can rely upon its dietary intake. It is likely, however, that under most field conditions recourse must be had to withdrawal of nutrients from the body reserves. While it is recognized that nutritional conditions in the wild are usually approaching the optimum at the time of birth, it is well to point out that the doe's condition is likely to be poor as a result of the strain of gestation coupled with food shortage or rigorous weather during the winter. Her reserves may be small or non-existent.

It is postulated that a large part of the postnatal mortality in fawns may be traced to inadequacies in lactation that prevent normal growth of the fawn and hence impair chances of survival.

LITERATURE CITED

ABDERHALDEN, E. 1898. Hoppe-Seyler's Z. Physiol. Chem. **26**: 489.

———. 1899. Hoppe-Seyler's Z. Physiol. Chem. **37**: 356–408.

Anon. 1950. Methods of Analysis. 6th Ed. Assoc. Official Agricultural Chemists.

COWAN, I. McT. and A. J. WOOD. 1955. The normal temperature of the Columbian black-tailed deer. Jour. Wildl. Mgt., **19**: 154–155.

ESPE, W. and V. R. SMITH. 1952. Secretion of milk. 4th Ed. Iowa State College Press, Ames.

HAGEN, H. L. 1951. Composition of deer milk. Calif. Fish and Game, **37**: 217.

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FOOD OF FUR SEALS TAKEN ON ST. PAUL ISLAND, ALASKA, 1954

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The purpose of this note is to add to the published information on the food habits of the northern fur seal (*Callorhinus ursinus*) in the vicinity of the Pribilof Islands. Mr. Richard E. Phillips aided in collecting stomachs and Mr. Ford Wilke in identifying their contents.

Fur seals assemble each summer in great numbers on the Pribilof Islands but comparatively little is known of their food habits there. Most biologists who have visited the Pribilofs during the commercial sealing season and who have examined stomachs on the killing fields, have found that few contained food. Lucas (1899) reported that of over 400 stomachs examined on the killing field, only seven contained traces of food (squid beaks, cod or pollack bones, and one large isopod). Elliott (1881) after examining "hundreds" of stomachs and relying on native testimony stated that ". . . in no single case has anything [food] ever been found. . ." in a stomach on the killing field. Reports by others are similar.

Until the present collection was examined, the food of the fur seal near the Pribilofs was known mainly from spewings found on the rookeries and hauling grounds. The predominant item which appeared there was small gadids, (Wilke and Kenyon, 1952).

During the 1954 sealing season a systematic effort was made to collect, on the killing fields of St. Paul Island, all stomachs containing food. The Aleut sealers cooperated by slicing open the stomach of each of 50,239 seals in the process of skinning. From these, 27 stomachs containing food were collected. About five others were lost because of confusion on the killing field. The approximate proportion of seals appearing on the killing field with an appreciable quantity of food in their stomachs thus appears to be about 0.06 per cent.

The stomachs were collected between June 26 and July 26, 1954, from immature male seals, 3 to 4 years of age. The contents ranged in volume from 20 to 700 cc., with a mean of 217 cc. All stomachs contained the usual roundworm parasites and nine contained small pebbles. Numerous small

amphipods and cumaceans were found in most; the presence of a number of intact sand fish stomachs, packed with these organisms, explained their presence in the seal stomachs (Table 1).

TABLE 1.—ANALYSIS OF THE CONTENTS OF 27 FUR SEAL STOMACHS FROM ST. PAUL ISLAND

Species	Frequency (stomachs)	Number of individuals per stomach (range)	Total individuals	Per cent (volume)
Sand fish, *Trichodon trichodon*.....	27	1–132	1327	94.2
Sturgeon-like sea-poacher, *Agonus acipenserinus*.....	5	0–6	13	5.6
Cod, *Gadus macrocephalus*.....	2	0–1	2	.2
Squid (sp ?).....	1	0–1	1	Trace

The stomachs came from seals which had completed feeding several hours before death and digestion had progressed to a considerable degree. Thus, the volume of remaining food has little significance. The number and approximate size of individual sand fish was ascertained by a comparison of bony remains with a preserved specimen. The majority of sand fish consumed probably weighed about 17 grams each and were between 10 and 13 cm. long; a few individuals were about twice this size. Based on these figures, the food in the stomach which contained the maximum number of sand fish (132) would have weighed about five pounds.

Among approximately 4900 fur seal stomachs previously examined, the sand fish and sturgeon-like sea-poacher were not recorded as food items. The parts of other species which appear in spewings on the rookeries, taken alone, fail to give a complete picture of the feeding habits of the fur seal in this area. Examination of pelagically collected stomachs is also necessary to complete the knowledge of food habits near the Pribilof Islands and in the Bering Sea, generally.

LITERATURE CITED

ELLIOTT, H. W. 1881. The seal islands of Alaska. U. S. Dept. Int., Tenth Census, Sect. 9, Monogr. A, pp. 1–176 and maps. (Reprinted, 1882 as Spec. Bul. 176, U. S. Comm. of Fish and Fisheries.)

LUCAS, F. A. 1899. The food of the northern fur seals. *In* The fur seals and fur-seal islands of the North Pacific Ocean. U. S. Treas. Dept., Doc. 2017, Part 3, p. 64.

WILKE, F. and K. W. KENYON. 1952. Notes on the food of fur seal, sea-lion, and harbor porpoise. Jour. Wildl. Mgt. **16**: 396–397.

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LARGE TRAPS FOR CATCHING QUAIL[1]

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In reviewing the literature on quail research it is noticeable that almost all quail banding studies have used the standard quail trap as first described by Stoddard (1931. The Bobwhite Quail. Scribner's, New York) or some modification of it. This "old reliable" trap has been indispensable because of its low cost and portability.

The purpose of this paper is to describe results obtained from the use of larger traps in locations where concentrations of western quail occur. Their usefulness in low quail densities where birds are not concentrated is not known.

In 1951 the Arizona Cooperative Wildlife Research Unit began research on Gambel's quail (*Lophortyx gambeli*) and scaled quail (*Callipepla squamata*) in which trapping and banding was an important part. At the beginning, only standard quail traps were used (1 by 3 by 3 feet). In 1952 larger traps were tried, and since then both trap sizes have been used.

Of the several sizes of large traps, the most common was 3 by 3 by 6 feet made of portable wooden frames and covered with one-inch-mesh chicken wire. The frame of another large trap, 3 by 8 by 12 feet, was made of iron pipe. Permanent traps made by driving steel posts into the ground to support chicken wire were also used. All traps had one-inch-mesh wire funnels at each end. A small gate, through which the operator could enter to take out the birds, was built into each trap. Traps were baited with milo maize or scratch feed.

During the period from 1952 thru 1954, 1,659

[1] A contribution from the Arizona Cooperative Wildlife Research Unit: University of Arizona, Arizona Game and Fish Commission, U. S. Fish and Wildlife Service and the Wildlife Management Institute cooperating. Charles R. Hungerford assisted with the trapping during the winter of 1952–1953.

quail were trapped near Oracle, Arizona. Many of these were retrapped many times and during several seasons. Comparisons of trap results based on 460 sets and a catch of 3,631 Gambel's quail are shown in Table 1. In this summary sets which yielded no

TABLE 1.—COMPARISON OF NUMBERS OF QUAIL CAUGHT IN TRAPS OF DIFFERENT SIZES BASED ON 125 SMALL TRAP RECORDS AND 335 LARGE TRAP RECORDS

No. of birds per catch	Percentage of times occurring	
	Small traps	Large traps
1–5	64.8	40.8
6–10	25.6	18.5
11–20	8.8	28.4
21–30	.8	10.2
31–40	....	1.8
41–50	....	.3

birds have been omitted because on many days no birds came near the traps. A total of 125 small trap sets averaged 4.7 birds per catch. Three hundred and thirty five large trap sets caught an average of 9.0 birds per set.

These figures indicate that the small traps have a capacity of about twenty birds and that this figure is seldom exceeded, while the large traps are capable of making catches above forty birds. While the small traps caught more than ten birds only 9.6 per cent of the time, the large traps caught more than ten birds 40.7 per cent of the time.

In addition to increased capacity, the large traps had the further advantage of preventing injuries such as "scalping," which sometimes occurred in low traps.

The only disadvantages found in the larger traps were that they were less portable and were bulky in storage. When traps were larger than 3 by 3 by 6 feet small birds which got into them were difficult to catch. Traps larger than this size, however, had no additional advantage. The traps now in most common use by this research unit are made of wooden frames with sides 3 by 6 feet and ends 3 by 3 feet. These frames are light enough so that one man can conveniently place them out or bring them in with a pick-up truck. When used along with small standard-type traps we have found that a maximum number of quail can be captured with a minimum of effort and expense.

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COMMENTS ON THE WINTER FOOD OF RED FOXES IN EASTERN SOUTH DAKOTA

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The data presented here were obtained from a study of the stomach contents of 26 red foxes (*Vulpes fulva*) taken from November, 1954 through February, 1955, in the vicinity of Redfield, Spink County, South Dakota. These foxes were shot from an airplane. Most of the animals were flushed from the tall grass bordering prairie sloughs which in winter affords the only cover of any extent in this area. The same cover provides the principal winter retreat of the ring-necked pheasant (*Phasianus colchicus*) which is common in Spink County.

Table 1 indicates the food items recovered from stomachs, the number of stomachs in which each was found, and the percentage of stomachs in which each item occurred.

The high incidence of pheasant remains in these stomachs is notable. Other studies of the winter food of foxes in the midwest do not record such a large percentage of this bird. In a study of the stomach contents of 45 red foxes taken during January, February, and March in Iowa, Scott

TABLE 1.—CONTENTS OF RED FOX STOMACHS

Species	Number and percentage of occurrence
Birds	
Phasianus colchicus	17 (65.4)
unidentified small bird	1 (3.9)
Mice	
Peromyscus sp.	7 (27.0)
Microtus sp.	4 (15.4)
Microtus ochrogaster	3 (11.5)
Microtus pennsylvanicus	1 (3.9)
Reithrodontomys megalotis	2 (7.9)
unidentified mouse	2 (7.9)
Rabbits	
Lepus townsendii	5 (19.2)
Sylvilagus floridanus	3 (11.5)

(Ecology, **36**: 366–367, 1955) found pheasant in only three. Hatfield (Journ. Mamm., **20**: 204, 1939) found pheasant in four of 29 stomachs of Minnesota-taken red foxes. In an extensive survey of food habits of foxes in Wisconsin and Iowa, Errington (Journ. Mamm., **16**: 192–200, 1935) found no pheasants in 46 winter-taken red foxes from Wisconsin, and four in 50 red and two gray fox stomachs taken in winter in Iowa. In an examination of the debris about 113 red fox dens in Iowa during spring and early summer Errington (*loc. cit.*) found remains of 314 pheasants. The same author found evidence of pheasants in 66 of 1175 fecal samples collected near red fox dens. He considered pheasants to be "over-represented" in den debris.

It seems generally conceded that availability of prey is a key factor in determining food habits of foxes. In Spink County in winter it is likely that the pheasant is the most abundant and easily available large prey item for red foxes. The birds are abundant and are especially vulnerable to predation in winter when the only cover available to them, as noted earlier, is that from which most foxes are taken.

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A STUDY OF THE FLEAS OF COTTONTAIL RABBITS IN NEW JERSEY[1]

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In November, 1949, the New Jersey Department of Conservation and Economic Development, Division of Fish and Game, with federal aid (Project W-22-R), began a study of cottontail rabbits (*Sylvilagus* sp.) in Hunterdon County, New Jersey, where rabbits had been imported for recreational purposes. Originally, rabbits were brought into the area from Missouri. Starting in March, 1953, they were imported from Wyoming, and starting in December, 1953, they were imported from Kansas.

Collections of fleas and other ectoparasites were made by the junior author by hand-picking them from cottontails captured in box traps. Rabbits were trapped in the townships of Franklin, Clinton, Bethlehem, and Union in Hunterdon County.

A summary by months of the data for fleas on cottontails is set forth in Table 1.

The seasonal distribution of adult fleas on cottontail rabbits follows a rather definite pattern. During the warmer months, *i.e.*, May, June, July, August, and September, the flea index for infested animals was only 4.1 fleas per rabbit. This number is low when compared with the flea index for the cooler months of the year, *i.e.*, October, November, January, February, March, and April when there was an average of 8.4 fleas per infested rabbit. No collections were made in December.

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, the State University of New Jersey, Department of Entomology, New Brunswick.

The majority of cottontail rabbits trapped were native to New Jersey and were infested with flea species that can be considered usual or native to New Jersey.

Cediopsylla simplex was the major species parasitizing cottontails in New Jersey, and it represented 88.41 per cent of the total fleas collected. This agrees with studies on cottontails in North Carolina (Shaftesbury 1934), where 98.1 per cent of the fleas collected were *C. simplex*, and in Missouri (Portman 1944), where 73 per cent of the fleas were *C. simplex*.

Odontopsyllus multispinosus was found to be rather common, comprising 6.76 per cent of the total fleas collected.

Ctenophthalmus pseudagyrtes and *Epitedia wenmanni* are both parasites of smaller animals, *i.e.*, mice, shrews, and moles, and their occurrence on cottontail rabbits is probably accidental. *Cediopsylla inaequalis inaequalis*, taken from Wyoming cottontails, and *Hoplopsyllus affinis*, taken from Kansas cottontails, are fleas foreign to New Jersey. They were most likely transported into this state on imported rabbits. Whether these two species are established in the state is not known.

Since fleas were transported into New Jersey on cottontails from Wyoming and Kansas, it may be assumed that they also have been brought into the state on Missouri imports, but this would be difficult to prove because fleas from Missouri cottontails are the same species as those from New Jersey cottontails.

TABLE 1.—MONTHLY TOTALS OF FLEAS TAKEN FROM 311 COTTONTAIL RABBITS FROM HUNTERDON COUNTY, NEW JERSEY, BETWEEN MAY 1950 AND FEBRUARY 1954

	Number of fleas taken in the indicated months											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Totals
Total fleas	152	430	232	79	22	8	36	195	123	703	91	2,071
Fleas per infested rabbit	8.0	11.3	8.6	6.0	5.5	2.6	4.5	4.5	3.4	6.3	10.1	6.7

This brings up the question of the wisdom of importing cottontail rabbits into New Jersey. Even though the above two species of fleas are not reported as being capable vectors of any disease, there still remains the possibility of introducing, on cottontails from the west, more potent disease vectors.

LITERATURE CITED

PORTMAN, R. W. 1944. Winter distribution of two ectoparasites of cottontail rabbits in Missouri. Jour. Econ. Ent., **37**: 541.

SHAFTESBURY, A. D. 1934. The Siphonoptera (fleas) of North Carolina, with special reference to sex ratios. Jour. Elisha Mitchell Sci. Soc., **49**: 247–263.

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PLASTIC NECK MARKERS FOR WOODCOCK[1]

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In 1954 and 1955, colored plastic markers of the type developed by Wint (1951. Improved method for marking game birds for identification in the field. Bull. Oklahoma A. and M. College, Stillwater. **48**(3): 1–7) for bobwhite quail were used on woodcock in central Maine. The results indicate that this technique is of definite value in studies of the behavior of woodcock on their breeding grounds.

Plastic material for the markers can be obtained from upholstery shops in any desired color. Two weights of plastic material were used; 20 and 12 gauge. Heavier material (20 gauge) seemed to be more satisfactory, since the lighter plastic markers tended to fold soon after being attached. It was found that light colors such as yellow and white were most easily seen. Tags of a standard size (Fig. 1) were cut from the plastic, and two holes were punched in the center of the marker approxi-

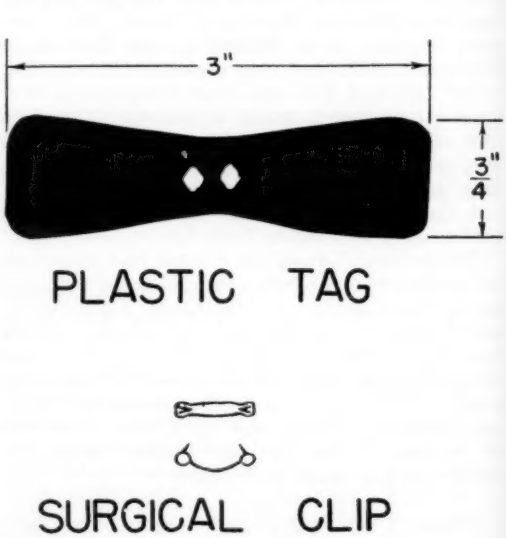

FIG. 1. Dimensions and design of plastic tags for marking woodcock.

[1] Contribution from the Maine Cooperative Wildlife Research Unit, Orono, Maine; Maine Department of Inland Fisheries and Game, University of Maine, Wildlife Management Institute, and the U. S. Fish and Wildlife Service cooperating.

mately one-tenth-inch apart. In order to obtain a variety of color combinations, bi-colored markers were made by heat-sealing a piece of plastic of one color onto the end of a tag of a contrasting color. An automatic iron set at medium heat was used to seal the two pieces together.

Markers were attached using Michels' "Justrite" non-corrosive, 14 mm. wound clips (Fig. 1). These clips were bent into a shallow "U" shape and pushed through the holes in the marker. The tag was then placed on the woodcock by lifting the loose skin on the nape of the neck (Fig. 2) closing

FIG. 2. Woodcock decoy with attached tag.

the clip with the fingers so that the barbs met and passed through the skin.

A total of 25 woodcock—22 males and three females—was marked with plastic bow ties in 1954 and 1955. Observations indicated that markers remained on the birds for at least three weeks when properly attached. In one case a male woodcock carried a tag for more than a year. However, another male marked in 1954 was recaptured in 1955 with no tag on it. The markers are useful primarily for short-term studies and should not be depended upon to last for a full year.

Field observations revealed that tagging with the plastic markers had no adverse effects on woodcock. Birds which had been tagged and recaptured showed no signs of infection or irritation. Tagged birds carried out their courtship activities on the singing grounds as would unmarked birds. The tags did not appear to interfere with the progress of the bird while it walked through thick cover.

Two female woodcock were captured in automatic traps placed on singing grounds, and one was captured on a nest. These were banded and marked. One of the females trapped on a singing ground was found later on a nest three-quarters of a mile away. The marker was readily visible when observed at close range. The tag did not appear to affect the activities of the incubating bird; the eggs were hatched successfully 18 days after the female had been marked.

The most important use of these markers is to aid in the study of movements of woodcock during the breeding season, which in Maine lasts from about April 1 to June 1. Individual males can be readily identified on singing grounds after being marked, and retrapping is unnecessary. Another important application of this marking technique may be to identify females on nests and with broods. On two occasions in 1954 tagged male woodcock were flushed from their daytime resting and feeding covers and were identified as birds marked on nearby singing grounds. However, the use of bow ties in this latter connection is not considered practical, since woodcock are seen for such a short time when flushed in thick cover that usually the presence of a marker cannot be determined.

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SEX DETERMINATION OF ADULT WILD TURKEYS BY MEANS OF DROPPING CONFIGURATION [1]

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Conservation Commission of W. Va., Charleston

During many years of turkey live-trapping and observations afield, the writer has concluded that the sex of adult wild turkeys (*Meleagris gallopavo silvestris* Vieillot) can be accurately determined by the relative size and shape of their droppings. The possibility of this means of sex determination was first brought to my attention by Fred A. Glover in 1947 during a turkey food habits study at Patuxent Research Refuge, Laurel, Maryland.

Droppings of the adult gobbler are straighter, longer and greater in diameter than those of the hen. The typical one has a curlicue on the larger end. In the fall, young-of-the-year gobblers may be separated from older gobblers by a difference in dropping diameter. Droppings of the latter may be as much as 15 mm. in diameter, while those of young gobblers seldom exceed 10 mm.

Hen droppings differ from those of the gobbler by their smaller diameter, from five to eight mm., and their looped, spiral or bulbous shape. When bulbous, loops or spirals are generally evident within the bulb. Hen droppings are shorter than those of the male (Fig. 1).

Ability to thus determine sex and, to a lesser extent, age, is of value to the selective hunter and to those engaged in the census, live-trapping or study of wild turkeys. When there is no snow, the selective hunter in search of a gobbler can determine whether one is among the flock that made observed scratchings or "sign." Wildlife workers engaged in turkey live-trapping can trap selectively when they know the sex of turkeys visiting specific or various traps. Many turkey flocks consist of gobblers only and it could be of value to the trapper to know whether a specific flock visiting a trap is thus composed.

FIG. 1. The five droppings left of center are those of female turkeys; the remaining four are male.

The writer has had little access to game-farm turkeys; hence, does not know the age at which differences in dropping configuration appear among poults. This may be worth investigation as a possible means of early sex determination of poults.

[1] A contribution of P-R. Projects 12-R, 19-D and 17-D.

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NOTES AND NEWS

Members and authors are advised that, from now on, manuscripts and correspondence relating to the *Journal* should be sent to Dr. Joseph J. Hickey, 424 University Farm Place, Madison 5, Wisconsin.

With the publication of the July issue, J. J. Hickey will succeed O. H. Hewitt as Editor of the *Journal*.